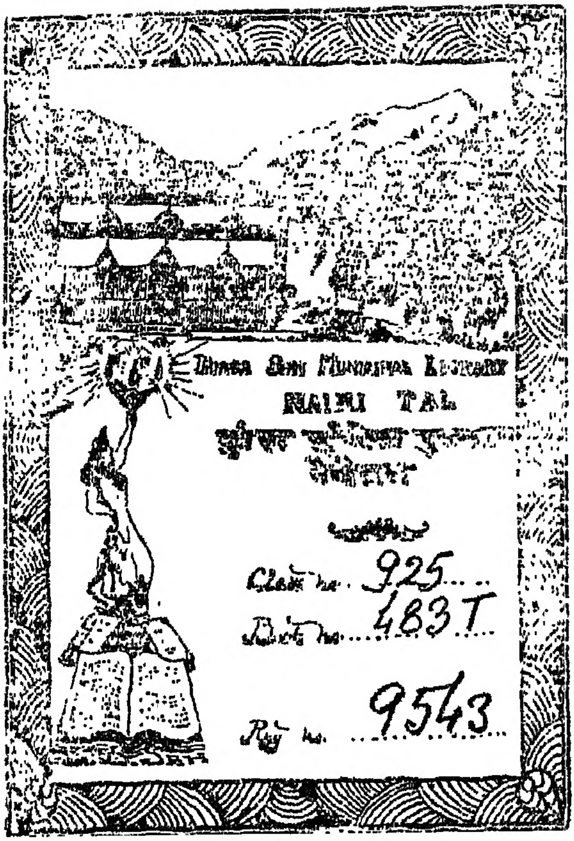
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THEY MADE YOUR WORLD

By Prof. A. M. LOW

Associate of the City and Guilds Institute; Member of the Institution of Automobile Engineers; Fellow of the Chemical Society; President and Fellow of the Institute of Patentees; Fellow of the Institute of Arbitrators; Fellow and Chairman Examining Committee Inst. of Chemist Analysts; Sometime Hon. Assist. Professor of Physics Royal Artillery College; Formerly Officer Commanding Royal Flying Corps Experimental Works; Fellow of the Institute of Commerce; Principal of the British Institute of Engineering Technology; Fellow of the Faculty of Science; Fellow and Past-President of the British Institution of Radio Engineers; Fellow Institute of Electronics; Past President British Interplanetary Society.

Illustrated by Amy Low

SCIENTIFIC BOOK CLUB

121 CHARING CROSS ROAD, LONDON, W.C.2

First published 1949

THIS BOOK IS PRODUCED IN COMPLETE CONFORMITY WITH THE AUTHORIZED ECONOMY STANDARDS

PRINTED IN GREAT BRITAIN BY EBENEZER BAYLIS AND SON, LTD., THE TRINITY PRESS, WORCESTER, AND LONDON AND BOUND BY NOVELLO AND CO., LTD., LONDON

Dedicated to

GERTRUDE ANNE DUNCAN LOW

INTRODUCTION

I once had the honour to explain an Exhibition of early scientific curiosities to a very distinguished and important personage. Among the quaint old electrical devices, simple chemical apparatus and hand-made instruments were the germs of almost every industry which serves us to-day. At the end of my very short descriptions I pointed to a vast hall full of every conceivable engineering device known to the world and said: "These, sir, arose entirely from the simple experiments of the pioneers whose apparatus we have just seen."

He looked at me blankly for a minute and then remarked: "Yes, Low, but what are they for?" To anyone with a spark of life-interest such a phrase would have been impossible, and it is for that reason that I dare be sure that a few facts about the lives of those who gave us everything in our world to-day must be interesting. These men were so very human, and there are so many more of our countrymen whose history should be told. For to them we owe all that we have.

CONTENTS

WILLIAM GILBERT, M.D.

1540–1603

In the reign of Queen Elizabeth there lived in the City of London at St. Peter's Hill a scholarly physician by the name of William Gilbert. A man well liked by his neighbours, a bachelor, but much given to entertaining others of his own kind, and one who spent a good deal of time carrying out experiments of every type.

This kindly scholar was, in fact, the Queen's physician. He has since been designated the "Father of modern electricity, and the Galileo of Magnetism". He belonged, not to the daring followers of Francis Drake, but to the ranks of thinkers and researchers who built so ably for those who followed after.

William Gilbert was born in 1540 in Colchester where his father, a reputable Suffolk gentleman, held the post of Recorder. There is little to tell of the boy's early life except that he went to a local school. Later, he graduated at St. John's College, Cambridge, where he was elected Fellow in 1561 and there took his B.A., M.A., and in 1569 his M.D. degrees.

Four years later Gilbert settled in practice in London where he soon began to make his name known. He became a Fellow of the College of Physicians, and in 1581 was given the office of College Censor, a post he held for seven consecutive years.

At his home at St. Peter's Hill, Gilbert and his scientific friends formed the nucleus of what was the first scientific association known in England and probably, also, the earliest in Europe.

It was not long before his reputation reached the ears of the Queen. She was interested to hear of his experiments, he was introduced to Court circles and made so great an impression on Her Majesty that she appointed him Royal Physician at the princely salary of one hundred pounds a year.

Gilbert had always been interested in the power of amber to attract other objects, when rubbed sharply against cloth or similar substance. Through his experiments he found that not only amber, but many other substances, possessed this same property which he named *vis electric*, after the Greek word elektron, meaning amber.

Gilbert proved that substances could be divided into two

classes, "electrics" which could be electrified by rubbing, and "non-electrics". He discovered also that electrified bodies lost their electricity if held near a flame or were otherwise heated, and that it was difficult to electrify them at all on a damp day.

His main claim to fame lies in his book *De Magnete* which appeared in London in the year 1600. It was the first great physical work published in England and was dedicated to "You

WILLIAM GILBERT

alone, the true philsophers, ingenious minds which not only in books, but in things themselves, look for knowledge".

The author never concealed his scorn for those who based their opinions on superstition, hearsay or speculation. His belief, like that of other great men, was in experimental work, not guesses.

On the appearance of *De Magnete* its merit was recognised at once in England and on the Continent. There is little doubt that Gilbert's outlook was in advance of his time, and his work

was a summary, not only of the knowledge of magnetism of his age, but of the next twenty years experimental research. It was the poet Dryden who prophesied that "Gilbert shall live till lodestones cease to draw".

The book begins with a summary of the existing knowledge regarding magnetism; then follows an account of the names of lodestones and their etymology, and the remainder is an investigation of the properties of magnetism, the attraction of magnets, their natural direction in relation to the poles of the earth and their variation and "declination".

His main and greatest conception that swept away so much superstition and false reasoning was that the earth is nothing but a large magnet, which explained not only the direction of the magnetic needle north and south, but its dipping or declination.

It was during the 11th century that a stone was first found in the earth which had the property of attracting iron and which, if suspended or floated in a container on water, would always come to rest with its long axis pointing in a north and south direction.

This lodestone, as it came to be called, opened up great possibilities in navigation, for in earlier times seamen did not care to venture far from shore when the only means of finding their position was by the stars. By the time Elizabeth came to the throne the mariners' compass was in fairly common use.

It was this property of magnetism that fascinated William Gilbert and led him to make the experiments finally embodied in his book.

In his experiments Gilbert used globular pieces of lodestone with a light, pivoted needle of any metal, and for electrical investigation he made a device called a versorium which was the earliest form of electroscope.

With small globes Gilbert demonstrated that they influenced the compass needle in the same way as did the earth. He repeated much of the work of Peregrinus who discovered the "poles" of a magnet, but Gilbert named these poles, the north austral and the south boreal. His work may be summed up in brief: he thoroughly investigated the properties of magnetism, he showed that the earth was itself a huge magnet, and he produced electricity by friction and distinguished between electrics and non-electrics.

When James I succeeded Elizabeth on the throne of England he confirmed Gilbert in the office of Royal Physician, but the latter did not long continue his work, for in 1603 he died at the comparatively early age of sixty-three.

Gilbert enjoyed fame in his lifetime and lived long enough to see his work crowned with success. *De Magnete* remains a fitting remembrance of a great scientist and indefatigable worker. His books, globes and instruments were all left to the Royal College of Physicians, but unfortunately were completely destroyed in the Great Fire of London.

WILLIAM HARVEY, M.D.

1578–1657

It was in 1616, the year that William Shakespeare died, that a London physician, Dr. William Harvey, during the course of some lectures to the medical world, announced his far-reaching discoveries concerning the circulation of the blood.

This thirty-eight-year-old doctor was to astonish the medical men of his time, and by his investigations into the working of the human body, to herald the beginning of modern physiology.

Harvey's early life was quiet and uneventful. He was born at Folkestone on 1st April, 1578, the second child and eldest of seven sons of a Kentish yeoman, Thomas Harvey. School days were spent at Kings School, Canterbury, and when these were ended Will Harvey went to Caius College, Cambridge, where he graduated B.A. in 1597.

It was always Harvey's intention to study medicine. In furtherance of this plan he went to Padua, and there at the famous school of medicine attended the candle-light lectures of Fabricius of Aquapendente, the great anatomist.

Under the influence of this master, Harvey became deeply interested in the work of Fabricius on the valves in the heart veins. It was then known that two types of blood vessels led from the heart, the deep-seated arteries and the veins near the surface.

Galen, a Roman doctor of the 3rd century, had attempted to explain the apparent beat of the heart and arteries by a back and forwards movement of the blood in the veins and arteries to and from the heart.

But, as Harvey observed, the vein valves opened in one way only—towards the heart, and he realised that it was therefore impossible for the blood to pulsate backwards and forwards.

What therefore was the explanation of the movement of the blood? He pondered the problem, turning it over and over in his mind.

In 1602 Harvey returned to England to take his M.D. degree at Cambridge, and then marry and settle down as a physician in the London parish of St. Martin-extra-Ludgate. Daily, he could be seen setting out on horseback to visit patients, followed by a man on foot, as was the fashion of his day.

The College of Physicians elected Harvey a Fellow in 1607 and two years later, in February 1609, he obtained the post of assistant physician at St. Bartholomew's Hospital. Eight months later the head physician, Dr. Wilkinson, died and Harvey received the appointment.

Once a week the worthy doctor attended the hospital. There he would sit at an enormous desk in the hall, while the patients

WILLIAM HARVEY

were accommodated on hard, wooden benches. In winter there would be a cheerful log fire in the huge fireplace; in summer, the open windows allowed the air to alleviate somewhat the stench of dirt and disease.

Since he left Padua Harvey had experimented. He was determined to prove whether or not his theory regarding the movement of the blood was correct. He experimented with animals and found that the blood moved round the body and returned again. He then tried ligatures upon human beings, binding a man's arm so tightly that veins and arteries were closed and no blood allowed to pass. Observing that the pulse in the wrist had stopped, he loosened the bandage. The veins below it swelled and knotted and the blood flowed again.

By his experiments he proved that the blood travels from the

heart by the arteries and returns via the veins, while the pump that keeps the blood moving is the heart itself.

It was in 1616 that Harvey gave the three lectures in which he first made his investigations public. The first lecture dealt mainly with the outside of the body, skin, fat, superficial muscles and abdomen. Each organ was described and fully illustrated.

In the second lecture Harvey spoke of the chest and its contents, his reference to the heart showing that his discovery of the blood circulation had been completed. He described the heart structure and the great vessels, explained contraction of the cavities, and the use of the valves, and ended by stating that he thus demonstrated that the perpetual motion of the blood in a circle was produced by the heart beats. Head, brain and nerves were the final subjects.

In these lectures Harvey proved himself to be a man of learning and of practical experience. Indeed, it was shown that he had dissected no less than eighty specimens of animals during his researches.

1618 saw Harvey appointed Physician Extraordinary to James I. Twelve years after his first statement of the circulation of the blood he published at Frankfurt a small quarto volume containing an account of his discovery under the title of *Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus.* The book contains seventy-two pages and two plates of diagrams. It is dedicated to Charles I and the king in his kingdom is compared to the heart in the body.

The book begins with an examination of some of the defects in Galen's theory, and the author describes in detail what he himself saw and handled in living and dead animals. He explains his experiments on the ventricles, auricles, arteries and veins, proves the rapidity of circulation and shows how the mechanism of the valves in the veins is adapted to favour the flow of blood to the heart.

Great praise and discussion, both in England and Europe, greeted the publication of Harvey's work which to this day stands as a classic memorial to its writer.

Harvey was a Royalist, a king's man, and in 1642 when the great rebellion broke out he left London in attendance on His Majesty. At the Battle of Edgehill in October of the same year soldiers of the Royalist army noticed a short, dark-haired man accompanied by the young Duke of York and the Prince of Wales crouching under a hedge.

Repeated admonitions to get into a place of safety failed to move Dr. Harvey who was supposed to be in charge of the royal children, until a bullet grazed the earth at his side. This

brought him to his senses, for all that history relates of the episode is that the party moved away to some more peaceful spot.

In the same year Harvey went to Oxford with the king, and in 1645 we hear of him accepting the wardenship of Merton College. This post he relinquished in 1646, after the surrender of Oxford, when he returned to London to live with his brothers, wealthy men who had managed to keep Harvey's small fortune intact during his absence.

His last published work was a treatise on "Generation" called *Exercitationes de Generatione* which appeared in 1651.

His death took place on 3rd June, 1657, after repeated attacks of gout. He was buried in the family vault at Hempstead in Essex. Many years later, in 1883, the coffin was removed to a marble sarcophagus given by the College of Physicians, and then placed in the Harvey Chapel erected in Hempstead Church.

The notes of Harvey's famous lectures are now in the British Museum, London, in their original form and binding, with the author's annotations in red ink and the initial "W.H." against statements which he considered to be pre-eminently his own.

THE HON. ROBERT BOYLE

1627–1692

THERE appeared in the year 1661 a book entitled the *Sceptical Chymist*, written by a distinguished member of the newly founded Royal Society, the Hon. Robert Boyle.

To succeeding generations Boyle became known as the Father of Modern Chemistry and in the *Sceptical Chymist* he dealt a blow to old scientific superstitions from which his opponents never recovered.

Before Boyle's theory was announced many scientific men held the views of Aristotle, that there were four different kinds of matter, called elements, earth, air, water and fire and that by changing the properties of any substance, such as its texture or outward appearance, it would thereby be turned into something different. There were others, too, who held to the theory of Paracelsus, produced in the 16th century, which substituted the three principles of mercury, sulphur and salt for the four elements of Aristotle.

Boyle, as well as others of his circle, felt that these theories were not entirely tenable; it was after long detailed investigation that the *Sceptical Chymist* was published.

It is written in the form of a conversation between the Sceptical, or Enquiring Chymist, and two other persons, one holding the views of Aristotle and the other that of Paracelsus.

Boyle, in the guise of the Sceptical Chymist, demolishes the argument that there is any shred of evidence to substantiate the Aristotelian or Paracelsus theories. He declares that an element is the simplest form of matter, that which cannot be resolved into any other substance. He urges the scientist first to carry out experiments to discover which substances are elements, meaning something which cannot be split up into different parts.

Boyle not only discovered much by his own research but he pointed the way to many other experimenters who followed. By his advice to look for the elements he set a fresh target of an entirely new kind. He instigated the search which led from a few elements to the discovery of over ninety which we know to-day. As the result of his work there came a new trend to scientific endeavour. His own definition of an element was "a substance incapable of decomposition".

Robert Boyle was an Irishman, one of a family of fourteen and a seventh son, his father being the Earl of Cork. He was born on 25th January, 1627, at the family seat, Lismore Castle, Ireland.

He was a precocious child. We learn that he spoke Latin and French at an early age and that when he was only eight years old was sent to school at Eton. After three years Robert

THE HON. ROBERT BOYLE

went for a short period to live in the care of a Devonshire parson at Stalbridge. In 1638, with his elder brother and a tutor, he left England to travel on the Continent.

Robert spent some years wandering abroad, finally returning to England on the death of his father in 1644 when he inherited the estate at Stalbridge.

For a time Boyle lived on the estate studying science and enjoying the company of other scientifically minded friends. He became a member of a group of scientists who held

periodical meetings in London and Oxford. A group that was to become the Royal Society.

In 1654 Boyle left Devonshire to live in Oxford. There he built a laboratory and engaged Robert Hooke as his assistant. And it was here that the two men carried out the experiments which resulted in their famous air pump.

Boyle was then investigating the properties of air and the propagation of sound. In 1660 he published a work entitled *New Experiments Physico-Mechanical Touching the Spring of the Air and its Effects, etc.*, which contained experimental proof of the proportional relations between spring, or elasticity, and pressure which was to be known as Boyle's Law.

In 1668 Boyle left Oxford to settle and live for the remainder of his life in London with one of his sisters, Lady Ranelagh.

Boyle was one of the founders of the Royal Society for the Improvement of Natural Knowledge. He was asked to be first President but refused because he held religious objections to taking the oath required on assuming office. He was, however, a member of the Council.

In spite of bad health for many years, Boyle was able to carry out a large number of experiments and was acknowledged by his fellows as a keen and highly intelligent observer. Throughout his life he was an ardent student of theology. He was kindly, witty, and of a most generous nature, giving large sums away for charitable work.

One of the many experiments demonstrated by Boyle before a meeting of the Royal Society was to prove that if a vessel is cleared of all air and an animal is placed in it the animal soon dies. He also showed that a lighted candle put into a container exhausted of air is at once extinguished.

One illuminating but little realised fact regarding Boyle and his fellow members of the Royal Society, is that these men were constantly discussing scientific matters which had connection with problems bearing upon mining and coal. Boyle himself carried out investigations to determine differences in coal and wood. Samples of fuel were analysed. Accounts of fires in coal seams and many other problems were continually investigated. It was Boyle's proclaimed belief that the scientist could do much for trade and for all technical industry.

Boyle died in London in 1692 on 30th December, and was buried at St. Martins in the Fields.

ROBERT HOOKE

1635–1705

THE theory of the cellular construction of plant and animal life is closely linked with the development of the microscope. It was the improvement in microscope lenses made in the 17th century that made it possible for men to look into a new world. A world hitherto quite invisible to the human eye.

For the first time scientists were able to examine with some accuracy many thousands of living and inanimate objects. Imperfect though it was, the microscope opened up a vast field of discovery.

Robert Hooke, brilliant if eccentric natural philosopher, was one of the foremost men of his day to make good use of the microscope in his research work. He investigated thousands of specimens and discovered many facts that had not even been suspected.

The results of Hooke's investigations were published in his greatest work *Micrographia*, the first book to deal only with microscopic observations, and a work exquisitely illustrated with finely executed drawings. The revelations of plant structure made by Hooke encouraged another English scientist, Nehemiah Grew, to continue his further researches, and led eventually to the beginnings of the cellular theory.

One of the cleverest and most prolific of inventors, Hooke, throughout his life, was hampered by a queer, uneven temperament. He would begin upon some line of research with great enthusiasm and without rhyme or reason would suddenly abandon it altogether. Worst of all was a secretive nature which led him to suspect his fellow scientists of wishing to profit by his discoveries. In many cases he kept his investigations unpublished for fear that others should make use of them.

Hooke employed the old method of writing an anagram when making the first announcement of a scientific discovery. The law of the spring, known as Hooke's Law, was given out by its discoverer as CEIIINOSSSTTUV. Two years later the description was published showing the anagram to be *Ut Tensio Sic Vis*, which meant that the pulling power of a stretched spring is in proportion to its displacement.

The strange, crotchety temperament was the outcome of an unnaturally dull and lonely boyhood. Robert Hooke was son

of a Minister of Freshwater, Isle of Wight. As child, he was so delicate that regular attendance at school was considered out of the question. Cut off from normal work and play with boys of his own age he retired deeper and deeper into himself and became engrossed in the making of mechanical toys. Here he showed real genius. He constructed hundreds of delightful

ROBERT HOOKE

models; a wooden clock that really kept time, a model ship and many other ingenious objects.

When his father died in 1648 Robert was sent to London to work in the workshop of Sir Peter Lely. From there he went to Westminster School where he learned Latin, Greek, Hebrew and Oriental languages. He must have made rapid progress for he is said to have mastered six books of Euclid in a week and learned to play the organ in twenty lessons.

From Westminster Hooke went on to Christ Church, Oxford, as a chorister and there his mechanical skill was soon brought to the notice of influential men. Already he had invented thirty different ways of flying, but it was not until 1655 that he ventured to show his ideas to John Wilkins, Warden of Wadham College.

Wilkins was so impressed with Hooke's skill and ingenuity

that he introduced him to the Hon. Robert Boyle. This was a lucky day for Hooke, for Boyle offered him work in his laboratory and Hooke was able to assist Boyle in the construction of his air pump.

It was not long before the Royal Society recognised the merit of Hooke's work. In 1662 he was offered the post of Curator of the Society's experiments. This Hooke accepted and two years later a special lecture of £50 a year was founded for his benefit and he was made a Fellow of the Society.

By this time Hooke had many inventions to his credit, amongst them one to regulate the movement of watches by the application of a balance spring. He had also accepted the professorship of mechanics and mathematics at Gresham College in Bishopsgate, London.

In the brain of the shrunken, ill-tempered scientist it seemed that idea crowded upon idea. He quarrelled with his fellow workers and other members of the Royal Society. He detested to disclose a single figure or one syllable of his investigations lest another should benefit. Yet he was respected for his brain, and accepted as a noted figure in scientific circles.

Of his inventions mention may be made of the marine barometer, the double barometer, a universal joint, and an improvement in diving bells. He showed the relation of barometric readings to weather changes, made an enormous pendulum 200 ft. long which he affixed to St. Paul's steeple in order to measure its vibrations.

By the use of their improvised air pump Hooke and Boyle established that without the presence of air combustion could not take place. Hooke believed that when combustion took place, in some manner the combustible was dissolved. Working on the problems of respiration he demonstrated that by forcing air through the lungs of an animal life could be maintained even though the lungs were motionless.

In *Micrographia* Hooke showed the earliest investigation of the colours of thin plates, and the first mention of the black spot in soap bubbles. Light he described as "very short vibratory motion", heat as "a property of a body arising from the motion of agitation of its parts".

During the time of the Plague Hooke left London, and was employed as assistant to Dr. Wilkins and Sir William Petty at Epsom. After the Great Fire he designed and constructed an excellent model for rebuilding the City of London, and although this was not used Hooke was given a lucrative post as Surveyor which enabled him to make several thousand pounds. Money, however, brought him little pleasure, for he was miserly in the

extreme, and after his death quite a large sum was found hidden away in an iron chest which he thought no thieving hands would ever discover.

In 1691 Hooke received the degree of Doctor of Physic at Doctors Commons. This was granted him by the Royal Society in order that he might complete certain inventions upon which he was then engaged.

It has been claimed for Hooke that he divined before Newton the true doctrine of universal gravitation, but that he had not the necessary mathematical ability to demonstrate its functions.

He died at Gresham College on 15th March, 1703, at the age of sixty-seven. That Hooke was a genius is undoubtedly true; had he not adopted a policy of reserve he might have accomplished much more, although change of character was not to be expected from one of his jealous disposition.

He was the first to state that the positions of the heavenly bodies should be regarded as a definite mechanical problem. He devised a system of telescopic signalling and anticipated Chladni's acoustic oscillation experiments made by strewing flour over a vibrating bell, as well as originating the idea of using pendulums as a measure of gravity.

NEHEMIAH GREW, M.D.

1641–1712

Up to the middle of the 17th century little was known of plant structure. "Green men" travelled up and down the country preparing herbal simples, herbalists taught their medicinal value, and the doctrine of signatures whereby the outward appearance of plants was believed to indicate certain curative powers for specific diseases, was widely accepted, but the existence of sex in plants was unrealised.

With the invention of the compound microscope, however, study of minute organisms and structures became possible. By the use of these instruments scientists were able to "check-up" on their work, and many former theories became facts.

Leeuwenhoek, a Dutch physicist, Malpighi an Italian doctor, and the English physician Nehemiah Grew, were all indebted to the new microscope for development of their work.

Another English scientist, Robert Hooke, published in 1665 a book containing his microscope observations on the cellular structure of living things and it is believed that Grew, who had been investigating plant anatomy without the aid of instruments, was thereby encouraged to make use of the microscope, and upon his investigations were laid the foundations of English botany.

Nehemiah Grew was born at Atherstone, Warwickshire, in 1641, and was the only son of a nonconformist Divine, Obadiah Grew, who attained some notoriety during the Puritan régime and later in the Restoration.

Nehemiah was educated at Pembroke Hall, Cambridge, and graduated B.A. in 1661. Even as a lad he was interested in plants, and on leaving Cambridge we hear of him studying vegetable anatomy with the encouragement of his half-brother, Henry Sampson.

So impressed was Sampson by Nehemiah's essay on *The Anatomy of Vegetables Begun,* that he showed it to the Secretary of the Royal Society who, in turn, handed it on to Bishop Wilkins, the President. The essay was read at one of the Royal Society's meetings, with the result that it was approved and an order made for printing. The author was honoured by election to the Society the same year.

Grew, who had decided to take up a medical career, and had been studying at Leyden where he obtained his M.D. degree, returned to England to set up in practice. His first medical work started in Coventry, but he later moved to London where he settled, married, and built up a successful and extensive connection.

In spite of many patients Grew still carried on his studies of

NEHEMIAH GREW

plant life. His preliminary essay, dedicated to Lord Brouncher, President of the Royal Society was published in 1672.

It is a fact that scientific research carried out in one part of the world is often duplicated in another, and some outstanding discovery announced in one country will be simultaneously published in another. While Grew was working in England on plant structures, the Italian, Malpighi, was investigating in similar directions and actually communicated results of his work to the Royal Society at the same time that Grew's paper appeared.

Several other papers were communicated by Grew to the Royal Society following the *Anatomy of Vegetables*, and so highly was his work esteemed that in 1672 he was appointed the Society's curator for plant anatomy.

Shortly after this he issued the *Comparative Anatomy of Trunks*, the corrected copy of which, with the author's notes, is now in the British Museum.

Besides plant research Grew was also investigating plant salts and colours, and his observations were published in a series of papers on *The Nature, Causes, and Power of Mixtures*.

His greatest work, *The Anatomy of Leaves, Flowers and Fruits*, was read to the Royal Society over a period from 1676 to 1677 during which time he became the Society's secretary and editor of its journal, *Philosophical Transactions*.

That Grew was also carrying on his medical practice is shown by his admission as a Honorary Fellow of the College of Physicians in 1680.

His book was issued in four parts. The first three being second edition of *The Anatomy Begun; The Anatomy of Rock;* and *The Anatomy of Trunks*. The fourth book, dedicated to the Hon. Robert Boyle, included the *Anatomy of Leaves, Flowers, Fruit and Seeds*, and consists of seventy-two pages and forty-two plates.

To Grew belongs credit for being the first to advance, from his observations, made with the naked eye and microscopically, the existence of sex in plants.

He claimed, and as we now know, rightly, that the stamens of flowering plants are the male organs, and that from their anthers is shed the pollen corresponding to the semen of the male human. The pistil of the flower is the female organ upon which the male pollen is scattered.

With a wealth of detail Grew described these sexual characteristics of plants, and his work remains an abiding example of patient investigation and scientific deduction.

Grew's last published work was a *Discourse of the Universe As It Is the Creature and Kingdom of God*. In this he directed his argument against Spinoza's doctrines, basing his belief in God on the "Necessity of His being and the Wonders of the World Around".

In temperament this hardworking physician and scientist was somewhat grave and thoughtful. But he was greatly beloved by his patients and had the reputation of a kind and generous disposition. Grew carried on his medical work up to the very last day of his life, and died suddenly while on his rounds on 25th March, 1712.

That he was learned in other branches of science besides botany and chemistry was probably true. In the funeral sermon delivered at the Old Jewry by one of his patients, the Rev. John Shower, it was stated that Grew was "acquainted with

astronomy and divinity and had read the scriptures in the original Hebrew".

Among the many subjects he investigated Grew dealt in papers with *Seawater Made Fresh*, and *The Nature and Use of Salts Contained in Epsom and such other Waters.* In his honour and to commemorate his name Linnaeus called a genus of trees *Grewia.*

SIR ISAAC NEWTON

1642–1727

To the non-scientific reader Isaac Newton's name usually conjures up a picture of an absent-minded Professor holding an egg carefully in one hand while he boils his turnip watch in a saucepan, or that of an elderly gentleman sitting under an apple tree who, when one of the fruits falls upon his head, exclaims excitedly that he has now solved the problem of gravity. Both these pictures are, indeed, founded on fact; the actual apple tree was growing up to 1820 and when it was cut down the wood was safely preserved. In recent years there has grown up a good deal of misconception regarding Newton's work. Einstein's theory of relativity has been so much before the public that Newton's teachings are looked upon as out of date, although Professor Einstein has acknowledged repeatedly the debt owed by science to his famous predecessor.

It was from the foundations laid by Isaac Newton that work in many branches of science developed. On the 200th anniversary of his death Einstein said of Newton that "his basic principles were so satisfying from a logical standpoint that the impulse to fresh departures could come only from the pressure of the facts of experience".

Among Newton's many discoveries was the binomial theorem, an algebraic formula used for transforming and clarifying algebraic expressions and elements of the differential calculus which he called Fluxions, denoting the rate at which variable increases or decreases at a given instant of time. He also demonstrated that experimental and mathematical methods must work together, and defined precisely such vague terms as "force" and "mass".

Newton did not discover gravity as is so commonly stated. What he did do was to demonstrate the universal nature of gravitation and explain the movements of the moon and other heavenly bodies.

The background of his life was a simple one. His people were of good yeoman stock, his father holding a small manor house and farm estate.

The elder Isaac Newton died some months before the birth of his son, which took place on Christmas Day, 1642, the same year in which the great Galileo died.

When her boy was two years old Mrs. Newton married the incumbent of a neighbouring parish, and young Isaac then went to live with his grandmother.

At the local school he chiefly distinguished himself by his skill in making mechanical models of clocks, kites, windmills and the like. One story claims that until he had fought and defeated the school bully, Newton had not troubled his head

SIR ISAAC NEWTON

about lessons although he was always a voracious reader. But it was said that he was so elated by his victory that he began to study in earnest and soon became head of the school.

He was fifteen when his stepfather died and his mother took him from school in order that he might learn to manage her farm. Here, Isaac was a complete failure. When he should have been farming he was reading mathematics or constructing models. It became too obvious to be ignored, and on the advice of an uncle it was decided that Isaac should be sent to Cambridge.

This was the turning point of his early life. At Trinity College there opened before him a new and wonderful world of learning. At school he read nothing but classics, now he was able to make rapid progress in science and mathematics.

He took his degree of Bachelor of Arts and then assisted the Professor of Mathematics with work on light, or optics, as the subject was then called.

It was by this time clear to all who came in contact with the handsome young student that he had a brain far above his fellows. His genius for mathematics was undeniable; he read and absorbed the most profound mathematical works without the slightest difficulty.

During 1665–66 when the Great Plague scourged England, Cambridge University was sent down, and Isaac Newton spent his leisure time studying difficult mathematical problems in the quiet seclusion of his country home.

He was greatly attracted by Kepler's work which proved that the paths of the planets round the sun were ellipses. Newton wanted to know why they moved and what was the force that pulled them towards the sun. Mathematically, he calculated that these elliptical paths would be traced by the planets if the attracting force varied inversely as the square of the distance between the planet and the sun. Briefly, the nearer the sun, the stronger the pull.

It was while pondering this matter one day in the orchard that Newton noticed the falling apple, and it then flashed across his mind that here was a body also influenced by a force working in accordance with the same inverse law as the planets.

Did the moon obey this law, he wondered, in its movements round the earth? Inspired to solve the riddle, he set to work upon more and more calculations. What he finally found was that a force acts between all masses of matter and varies according to the intervening distance in the same way. In other words, this was the Universal Law of Gravitation.

In 1667 Newton was made a Fellow of Trinity, and two years later, at the age of twenty-seven, he was given the Chair of Mathematics which he held for the next twenty-five years. He was also elected a Fellow of the Royal Society about the same time. The name of Isaac Newton was already honoured in scientific circles and his genius widely acclaimed.

After William of Orange became king the coinage of the country was found to be much debased. Newton was offered the position of Warden of the Mint, work that could be carried out without requiring his resignation from University activities. So ably did he acquit himself in his new duties that within three

years he was promoted Master of the Mint when he superintended the recoinage of British money, and was responsible for prosecution of clippers, counterfeiters and coiners.

In spite of his multifarious duties Newton mainly devoted himself to scientific investigation in optics, mathematics and astronomy. Before his discoveries, the riddle of colour was unexplained and he was the first to demonstrate how the colours of the spectrum were produced.

It is interesting to read his own description of one of his experiments. "In the year 1666 I procured me a triangular glass prism to try therewith the celebrated phenomena of colours. And in order thereto having darkened my chamber and made a small hole in my window-shuts to let in a convenient quantity of the sun's light I placed my prism at the entrance that it might be refracted on the opposite wall. It was at first a very pleasing divertissment to view the vivid and intense colours produced thereby."

Newton's explanation of the light split up by the prism into its component colours was that between the red and violet ends of the spectrum are arranged all other colours. All these colours, he stated, are already present in white light. The prism separates them in space. Each colour is refracted and separated from the others when the light leaves the prism. In the case of a rainbow, drops of water take the place of the prism.

From his experiments, Newton's conclusion was that light is a stream of tiny particles emitted from the source of illumination. He held that light is essentially corpuscular in its nature, and for a hundred years his theory held sway. To-day science states that light is an electro-magnetic oscillation, a vibration of the ether. It was, however, the genius of Isaac Newton that blazed the trail for others to follow and from which new discoveries were made.

Arising out of his experiments with light Newton invented a novel type of telescope where a curved mirror was used to collect the light. His own instrument is now a treasured possession of the Royal Society, and a 100-inch telescope is being built to be set up as a national memorial in his honour.

Newton's scientific work, claimed to be the most outstanding in the history of science, *The Philosophia Naturalis Principia Mathematica*, was published in 1687, a later book entitled *Optics* appeared in 1704.

As a token of the respect in which his name was held Queen Anne conferred on him the Order of Knighthood in 1705.

During his lifetime Newton collected a large and valuable

library. After his death this was sold for a paltry £300 to a Warden of the Fleet Prison, who later sent the books to his son, a clergyman living near Oxford. It seems incredible, but is none the less true, that for more than two hundred years these precious volumes lay unregarded, some in an old rectory and some in a country house in Gloucestershire.

To-day, thanks to the work of the Pilgrim Trust, more than 800 of the books have been bought for the nation and will be housed in a suitable library.

Newton foreshadowed many future scientific developments. He deduced the size of atoms, he suggested that the atomic nuclei of gold might be made to ferment and turn into "another body", and he forecast ideas of atomic structure as well as the transmutation of elements.

In appearance Newton was good-looking, hardly above middle height, but with "lively eyes". It is said that he never wore spectacles and that to his dying day had lost no more than one tooth.

Generous in temperament, open-hearted and honest as the day, Newton was a giant among men. Voltaire said of him that "if all the geniuses in the world were assembled together Newton would lead the band".

When he died at Kensington in 1727, having lived through six reigns, the world was the loser. He lies in Westminster Abbey and on his monument appears this inscription: "Let mortals congratulate themselves that so great an ornament of the human race has existed."

JOHN FLAMSTEED

1646–1719

In the year 1676 there went to live at the newly built Royal Observatory at Greenwich, John Flamsteed, first Astronomer Royal under warrant of King Charles II, and under direction of that monarch to "apply himself to the rectifying of the tables of the motions of the heavens and places of fixed stars in order to find the longitude of places for the perfecting of the art of navigation".

To this crotchety but brilliant British astronomer was due the first British catalogue of fixed stars; modern astronomy may be said to date from the year when John Flamsteed began his observations.

Flamsteed was a man of great courage who fought a constant battle against increasing ill-health. In his own branch of science he excelled, due in great part to his perseverance, and meticulous detailed observation. Indeed, it was his refusal to publish results of his work before they had been checked and re-checked to his entire satisfaction that led to the unfortunate quarrels between Flamsteed and his fellow scientists.

Son of a maltster of Denby, near Derby, John Flamsteed was born in 1646 and was educated at a local free school. According to his own memoirs, when he was fourteen he "got a great cold" which was followed by five years of sickness from which he never wholly recovered.

Two years later Flamsteed began to study mathematics and to try his hand at making measuring instruments. Soon he was engrossed in astronomical calculations, and from a book called *Street's Caroline Tables* he calculated eclipses, the positions of the planets, and wrote his *Treatise of the Equation of Days*.

In 1669 Flamsteed sent a paper of his observations to the Royal Society signed *In Mathesi a sole Fundes*, an anagram of his name Johannes Flamsteedius. His work was evidently already coming to the notice of scientific men, for Secretary Oldenburg replied direct to Flamsteed and correspondence passed between them.

Shortly after this Flamsteed made the acquainatance of Sir Jonas Moore, Governor of the Tower, who proved to be a good friend and provided him with several valuable instruments.

Flamsteed entered Jesus College, Cambridge, in 1672 and

in 1674 took his M.A. degree. He was later ordained into the Church of England.

It was in 1674 that Flamsteed stayed as a guest at the Tower, and on the advice of Sir Jonas Moore drew up a Table of Tides for the King, supplying His Majesty and the Duke of York with a barometer and thermometer made from models, together with a set of rules for forecasting the weather by them.

JOHN FLAMSTEED

At this time a Royal Commission was to be set up to examine a scheme put forward by a Frenchman, the Sieur de St. Pierre, for finding longitude at sea. Sir Jonas Moore arranged for Flamsteed to be made a member of this Commission and the latter was able to show that the Frenchman's suggestions were of no practical use.

Moore then approached Flamsteed with a proposition for him to direct a small private Observatory to be built at Chelsea. Before anything was done in the matter, however, another and higher post was offered Flamsteed.

Faced with the urgent need for improved astronomical tables for sailors in order that they might be able to determine positions at sea with reasonable accuracy, Charles II had decided to build an Observatory. Plans were drawn up to the design of Sir Christopher Wren for a building on the hill in Greenwich Park, and John Flamsteed was asked to become the first Astronomer Royal at an annual salary of one hundred pounds.

Flamsteed accepted the post, and on 10th August, 1675, the foundation stone was laid and the new Astronomer Royal constructed a "Scheme of the Heavens" at the very moment that the stone was set. Whatever astrological predictions Flamsteed may have made on this map were not left in writing for posterity to read, but the fact that he drew it up may be taken to show that he was in the habit of practising astrology.

Life was no bed of roses at Flamsteed House, as the Observatory was then popularly called. There were no instruments other than those given by Sir Jonas Moore and those belonging to Flamsteed. So meagre was the salary that the Astronomer Royal had to take pupils from Christ's Hospital in order to supplement it, and his annual payment from the Observatory was actually subject to tax.

Flamsteed was in continual trouble with his fellow scientists. He was a man who detested interference, and his reluctance ever to give any information unless he was convinced it was absolutely correct led to quarrels with other investigators.

He lost sight of the fact that he was a public servant, and it was only with the greatest difficulty that Newton, who needed data for work on his lunar theory, could drag the necessary figures from the angry Astronomer Royal.

It was little wonder that in spite of a genuine liking for Flamsteed, Newton revolted against this doling-out process from Greenwich and led a movement for the immediate communication of certain vital figures.

In April 1704 Flamsteed's catalogue of fixed stars was considered by Newton to be ready for publication and he consequently offered to enlist the help of Prince George of Denmark in raising the required funds. Flamsteed, however, was furious, he refused to submit his figures and accused Newton of wanting to take all the honour for himself.

Finding that Flamsteed was as stubborn as a mule in the matter, the Royal Society, convinced of the necessity for publication, set up a small committee, including Newton and Sir Christopher Wren, to report on the possibility of printing those of Flamsteed's figures already available. Arrangements were made and the printers instructed.

Flamsteed put every obstacle in the way, but by Christmas 1707, a volume of *Observations* made with the sextant, were printed, but not published. Finally, a Royal Order, dated December, 1710, given by Queen Anne, empowered publication, and in 1712 the *Historia Coelestis* appeared. Flamsteed immediately declared that the catalogue was imperfect, and on

the death of the Queen in 1714 he managed to get possession of 300 unsold copies which he then burned.

It was unfortunate that the first Greenwich Star Catalogue should have come into being in this way and caused so deep a rift in the relations between Newton and Flamsteed.

When Flamsteed died a few years later in 1719, the great task which he had set himself and for which he fought so strenuously was still unfinished. Thanks, however, to the unswerving loyalty and skill of his assistant, Joseph Crosthwait, his notes and observations were collected, and shortly after his death edited and published in three volumes under the title of *Historia Coelestis Britannica.* They remain an undying testimony to his genius.

This collection of observations, made with the aid of telescope and clock, was the first of its kind. Flamsteed, at his own cost, set up a mural quadrant of fifty-inch radius with the aid of which he took altitudes of stars with an estimated error of half a minute.

He married a London woman who outlived him, and in his private life was a dearly loved man of pious and abstemious habits. His work vindicated the attacks made on his skill and seamen came to depend implicitly upon the star maps and astronomical tables issued by the Greenwich Observatory.

EDMUND HALLEY

1656–1742

EVERY Thursday evening between the years 1721 and 1737 a highly select, and at the same time highly brilliant circle of scientific gentlemen, would dine together at some notable Coffee House in the West End of London before attending the meetings of that august body, the Royal Society.

Amongst this group might be noticed a tall, spare man, who seemed always to speak and act "with an uncommon degree of sprightliness and vivacity" and who was a universal favourite with the rest of the company.

This was Edmund Halley, the Astronomer Royal, and one who was second only to the great Sir Isaac Newton amongst scientists of his own day.

To-day, Halley's name is probably best known in connection with the comet called after him, but he has other and better merited claims to fame.

Edmund Halley was an only son, his father being a rich soap boiler in the City of London. Resolved that his boy should have every chance of developing talents which were evident at an early age, Edmund Halley, the father, sent his son to St. Paul's School, where he shone brilliantly at classics and mathematics and rose to be School Captain when only fifteen.

Throughout his schooldays young Edmund gave every spare moment to experimental study, and when he left St. Paul's to enter Queen's College, Oxford, he took with him, among other apparatus, a twenty-four feet telescope through which he observed sunspots and the occultation of Mars.

Before he was twenty, Halley had written and sent to the Royal Society *A Direct and Geographical Method of Determining the Elements of the Orbits of the Planets*, and invented "an improved construction for solar eclipses".

With a rich father, Edmund Halley was lucky enough to receive an ample allowance which enabled him to devote his time to the observations which interested him so keenly; he had not the drag of being obliged to earn his daily bread.

During his early investigations Halley found many errors in the star tables then in use. Flamsteed, then Astronomer Royal, and Helvetius, were engaged in cataloguing the places of fixed

stars in northern latitudes, so Halley decided to carry out observations on those in the southern hemisphere.

He decided, somewhat unfortunately, to go to St. Helena. With a recommendation from the King himself he obtained transport facilities from the East India Company, and embarked in November 1676. The climate of St. Helena, however, proved most unfavourable for Halley's work and he could only

EDMUND HALLEY

catalogue 341 stars. During the voyage, however, he was able to improve the sextant and collect data regarding the ocean and atmosphere.

When he returned to England in October 1677 Halley presented the King with a planisphere of the southern constellations which included the "Robur Carolinum" added by himself. This star catalogue was presented to the Royal Society with an appendix proposing the amendment of the lunar theory.

The reply of the Society was to elect this gifted young scientist as one of their Fellows, and six months later to send

him to Danzig as arbiter in a dispute between Hooke and Helvetius on the vexed problem of the advantages of telescopic, as opposed to plain sights.

In 1680, while enjoying a continental tour, Halley observed, near Calais, the great comet of that year, and his calculations were subsequently useful to Newton in fixing the comet's orbit.

Shortly after this he met and married an English woman, daughter of a London accountant, and moved from Islington to Golden Lion Court, Aldersgate Street, London, where the lunar observations, so dear to his heart, were continued.

Two years later, in 1684, Halley's father died, and it was then found that the soap business had so far declined that instead of the ample competence to which he was accustomed Edmund was left a comparatively poor man.

It was in August that year that Halley visited Cambridge in order to obtain certain figures of planetary motions. He called on Newton, who gave him the necessary information and from this meeting began a friendship which lasted throughout his life.

Although now far from rich Halley was instrumental in persuading Newton to give his great work *Principia* to the world, and actually undertook the cost of printing from his own pocket.

From 1685 to 1693 Halley acted as assistant secretary to the Royal Society in addition to editing its *Philosophical Transactions* to which he made many valuable contributions. In 1696, through the good offices of Newton, he was appointed a Deputy Controller of the Mint at Chester, a post which he held for two years.

William III, hearing of Halley's success in astronomical matters, gave him command of a warsloop, *Paramour Pink*, with instructions to study the variations of the compass and endeavour to find out what land lay to the south of the western ocean.

After a false start, due to a mutinous crew, Halley finally set off in September, 1699, and this time was able to explore the Atlantic from shore to shore. He arrived back in England in 1700 and his general chart of the variation of the compass appeared in 1701.

So pleased was the King with this work that in the following year he ordered Halley to make a survey of the tides and coasts of the British Channel, the results of which were published in map form in 1702.

Halley was later sent by Queen Anne to inspect the harbours of the Adriatic, and in 1703 was appointed Savilian Professor of geometry at Oxford.

It was ten years afterwards that Halley was appointed Astronomer Royal in succession to John Flamsteed, with an annual salary of one hundred pounds. He continued this work until his death in 1739.

While observing the paths of comets through the heavens Halley found that many of those seen in the early days showed great similarity to each other in their movements, and he believed that these were fresh appearances of the same comet. His calculations of the 1622 comet, coupled with his prediction of the date of its return, was strikingly verified by its appearance on Christmas Day 1758. Halley also indicated a method still used for determining solar parallax by means of the transits of Venus.

Among his many achievements was the detection of the long inequality of Jupiter and Saturn and of the acceleration of the Moon's mean motion; the discovery of the proper motions of fixed stars; the theory of variation and the suggestion of the magnetic occurrence of the Aurora borealis.

His most celebrated work was the *Astronomiae Cometicae Synopsis*, sent to the Royal Society in 1705 and published in English at Oxford the same year.

Halley died on 14th January, 1742; cheerful and with a clear mind to the end. He was survived by two daughters.

JAMES BRADLEY

1695–1762

MANY great scientists have figured in the list of Britain's Astronomers Royal. Following John Flamsteed and Edmund Halley, first and second holders of the office, came James Bradley, like his predecessors a man of brilliant scientific attainments whose interest in astronomy and natural philosophy began during schooldays, and whose work, while he was still a student, was known to the Royal Society.

Bradley has been aptly designated the founder of modern observational astronomy. His two major discoveries, the nutation of the earth and the phenomenon known as the aberration of light, made it possible for the first time to gauge accurately the position of the stars and the movements of other celestial bodies.

He possessed, said one of his contemporaries: "A most extraordinary clearness of perception, both mental and organic, a rare accuracy in the combination of his ideas, and an inexhaustible fund of industry and patient thought." Indeed, for Bradley, in his researches, nothing was too small, nothing too much trouble for the closest investigation.

Third son of one William Bradley, James was born in Gloucestershire in 1693, his father being a member of an old Durham county family.

After early education at Northleach Grammar School, James was admitted to Balliol College, Oxford, in 1711, and there obtained his B.A. and M.A. degrees.

The man to whom Bradley owed much of his later success was the Rev. Joseph Pound, Vicar of Wanstead, uncle on his mother's side of the family. Pound, who was one of the best known astronomical observers in the country, had a great appreciation of his nephew's ability, their bond of union being a devouring interest in all matters pertaining to astronomy.

It was through his uncle that Bradley was introduced to Edmund Halley who considered him a young man of great promise, and who, in 1718, proposed him for election to the Royal Society with the consent of the President, then Sir Isaac Newton.

At twenty-three Bradley communicated to the Royal Society certain of his observations on the Aurora, and some of his

calculations were printed in Halley's *Planetary Tables* of 1719.

Since boyhood, Bradley had been destined for the priesthood, and when offered the country living of Bridstow in 1719 he was forthwith ordained deacon and two months later became a priest. But Bridstow did not see much of its youthful pastor, for Bradley was very shortly after given a more remunerative

JAMES BRADLEY

living in Pembrokeshire, in addition to a chaplainship to the Bishop of Hereford.

It was, however, the heavens in general and not Heaven in particular that really interested the Reverend James Bradley. Despite his clerical duties he continued to pursue his experiments and observations in conjunction with his uncle, and when in 1721 the vacant chair of Astronomy at Oxford was offered him he at once resigned his preferments and accepted this new post.

On the death of his uncle in 1724 Bradley went to live with an aunt at Wanstead, and in the upper room of her house set up his own instruments for observation. It was while attempting to measure the distance of some of the stars that Bradley made his first great discovery.

During the month of December, while observing the movements of *Beta Draconis* he was startled to notice that instead of

the star moving northward as he expected, it moved to the south, and in the following April he noted that it turned again north.

For a year he closely watched this star to find that it described an ellipse, returning to the same position in which it had been a year before.

This movement, which Bradley found was common to most stars, was a poser to him. He considered it from every angle. Was it, he wondered, that the earth wobbled as it revolved on its axis? Hardly likely, he concluded, as his own observations failed to prove this hypothesis.

Then by a stroke of fortune, coupled with his ability for careful observation, Bradley found a clue to the solution of the puzzle.

While enjoying a sail on the Thames one sunny day he saw that the wind seemed to shift with the movement of the boat. On enquiry, the boatman told him that the changes in direction of the vane at the mast head were due to changes in the boat's course. The wind really remained steady.

Bradley immediately fastened on to what he believed was the answer to his problem. It was the movement of the earth in its orbit which caused the displacement. In the case of the stars, to a stationary observer a star would appear to be stationary, but to an observer on the far from stationary earth which revolved round him at eighteen miles a second, that star would appear displaced in the direction of the earth's motion.

While the earth completes an orbit the star appears to move in an ellipse in the same path. Bradley showed how the progressive transmission of light, combined with the movement of the earth, caused this annual shift of direction by heavenly bodies to an extent dependent upon the relationship of the velocities of light and the earth.

The discovery of the aberration of light was communicated to the Royal Society in 1729. The second of Bradley's great discoveries, the nutation, or nodding of the earth, was not announced until many years later, after he had tested its accuracy by investigation of an entire revolution of the moon's nodes over a period of eighteen years.

It was in 1742, after the death of Halley that Bradley was appointed Astronomer Royal. During his tenure of office at Greenwich he was responsible for the accumulation of material of immense value for astronomical work. Money was scarce, he received only a pittance, but by expenditure of a thousand pounds from the sale of old naval stores Bradley was able to lay the foundation of a useful astronomical outfit.

After twenty years of patient work Bradley decided to disclose his discovery of the earth's nutation. He therefore communicated it in a letter to the Earl of Macclesfield which was subsequently read before the Royal Society. This earned for Bradley the Copley Medal and an exemption by the Society of the payment of any further subscriptions.

From all over the world scientists wrote asking for his advice, or sent him their own observations. He became a member of the Council of the Royal Society, he was admitted to the Berlin Academy of Science and to the French Academy also. Everywhere he was held in the highest esteem both for his genius and for his upright and modest character.

Bradley married in 1742, but there now remains no direct descendant to carry on his name, for the family died out in 1806.

After twenty years of strenuous work at the Royal Observatory Bradley fell ill and died in 1762 in his seventieth year. The publication of his observations which filled fifteen MS. volumes, was delayed by disputes concerning their ownership. Finally they appeared, issued by the Clarendon Press, Oxford, in two parts, dated 1798 and 1805.

JAMES HUTTON

1726–1797

From earliest times man has gazed with awe at the heavens and striven within his narrow limits to trace and explain the movements of the heavenly bodies. Strangely enough, he neglected to study the earth on which he lived, and until the 18th century little was known and little effort made to learn more about its physical features.

But at the end of the 18th century rapid development of industry led to the expansion of mining coal and ores, and hence the study of rocks and minerals became of vital importance.

At this time a small band of scientists undertook geological study, both in Britain and abroad. Of these pioneers a German, Professor Abraham Gottlieb Werner, became famous both for his teaching of the science of minerals and rocks and for the doctrines he advanced.

Briefly, Werner taught that all existing rocks were deposited originally from primeval hot water by precipitation. Because of this belief he and his students of the School of Mining at Freiberg were known as Neptunists.

The Wernerian doctrine spread rapidly, but there was another school of thought which opposed his theory. The members of this school were called Plutonists, and they maintained, among other things, that the rocks of earth's crust were formed from consolidated molten material.

Chief of the Plutonists was the English natural philosopher and geologist, James Hutton, whose investigations laid the foundations of the science of geology as we know it to-day, and whose original treatise *The Theory of the Earth* overthrew the teaching of Werner and his followers.

Hutton was a Scot, born in 1726, in Edinburgh, the son of a well-to-do merchant of that city.

His childhood was uneventful. The elder Hutton died when James was still a child. When old enough the boy went to school in Edinburgh and later to Edinburgh University. His great interest, even from childhood, was in chemistry, and when in 1743 he was apprenticed to a Writer to the Signet he devoted most of his time, not to the study of law, but to making chemical experiments.

Deciding that the legal profession was not for him, Hutton soon gave up legal work to study medicine in Edinburgh and Paris, finally taking his M.D. at Leyden in 1749.

But, again, he found that his heart was not really in his work. He felt he would never really enjoy the practice of medicine and in 1750 he abandoned any idea of doctoring and turned instead to agriculture.

JAMES HUTTON

Eventually, he settled on land that he had inherited in Berkshire, and was there able to put into practice improved methods of tillage and study soils and minerals.

About this time Hutton made a lucky business partnership with a man called Davie with whom he was associated in the production of sal ammoniac from coal soot. Indeed, so successful did this business prove that it provided Hutton with a steady income for the rest of his life.

He was a good farmer. But throughout his life on the land he never ceased to experiment, to observe and record those features of the earth that held for him so great a fascination.

In 1768, having made sufficient money for his needs, Hutton leased his farm and moved back to Edinburgh to take up the reading of science. It was while studying the rocks of his native land and the Continent that Hutton gradually came to the conclusions that were to make his name famous.

He was convinced that the Werner theories were wrong, and by his own observations and study of hundreds of works of travel he amassed a vast store of information regarding the earth and its rocks. Hutton was not only a theorist, every conclusion he drew had its foundation in fact. His was the "seeing" eye of the man of science, he looked, as it were, behind the scene, and in his mind was certain that processes working over countless eons of time had formed the rocks and other of earth's features. To him it was crystal clear that what he saw happening around him in nature had also occurred in past ages. Everywhere decay and repair worked before his eyes.

Yielding at last to the urgency of friends, in 1785 Hutton read to the Royal Society of Edinburgh his first paper on *The Theory of Earth.* It was favourably received, but unhappily Hutton's style was dull and unattractive, and his theory so unorthodox that many of those who heard it read could not be bothered to work out its real significance.

Detractors did their best to demolish his theory. In 1793 an Irishman bitterly attacked him. Hutton was ill at the time but he was so incensed that he began at once to revise his paper and within two years the revised work was published in two octavo volumes.

In *The Theory of Earth* Hutton established the existence of two main groups of rocks, those formed from sediments, either from land, in the sea, or lakes, and those formed by consolidation of molten material. An explanation was also advanced of the occurrence of mountains and valleys and the slow changes they undergo.

Hutton wrote: "This subject seems important to the human race, to the possessor of this world, to the intelligent being, man, who foresees events to come and who in contemplating the future is led to enquire concerning causes in order that he may judge of events which otherwise he could not know."

He taught that the geologist could see no beginning and no end to his work. Earth's changes were slow movements. So gradual, so vast that man could only read them from study of their past. He showed that long periods had to be reckoned with and his theory of the time-scale influenced all branches of science.

Besides his famous *Theory of Earth* Hutton also wrote the

Theory of Rain and published a work entitled *Dissertations on Various Subjects in Natural Philosophy* which appeared in 1792 and treats of such matters as light, heat, fire and gravitation.

Hutton was a kindly, unassuming man. He never married, and lived a quiet retired life with his sisters. As a friend he was candid but affectionate, and he moved in the society of learned men an ever respected and loved colleague.

Although he ranks as the first British geologist of note it was not until after his death in 1797 that the real value of his work was appreciated.

It was his friend, John Playfair, who publicised *The Theory of Earth* by publishing a work of his own, the *Illustrations of the Huttonian Theory*, in which he discussed and explained Hutton's work.

During his later years Hutton was working on another book, *The Elements of Agriculture*, but he died before its completion and it was never published.

THE HON. HENRY CAVENDISH

1731–1810

AMONGST that select band of 18th century scientists already mentioned, who used to dine together every Thursday evening before the meetings of the Royal Society, might be noticed a tall, spare man, uniformly dressed in drab attire, who spoke seldom to his fellow diners, but none the less appeared keenly interested in the talk going on around him.

This was the Hon. Henry Cavendish, a man whose brilliant achievements in chemistry were to make his name famous. Many of his experiments, unfortunately, were not revealed until after his death, to such lengths did Cavendish carry his hatred of publicity. Indeed, it was claimed that no man who lived as long as did Cavendish, ever spoke so few words. His life was that of a recluse. He never married, and so great was his detestation of women that his female staff were never allowed to appear before him, the orders for the cook being left by Cavendish each day upon the hall table.

It is owing to this dislike of society that most of the early life of Cavendish is unknown. He was born at Nice on 10th October, 1751, second son of Lord Charles Cavendish, and was educated, first at a London school and then at Peterhouse College, Cambridge.

He seems to have acquired from his father a taste for experimental research, and as a rich man's son Cavendish received an ample allowance which enabled him to indulge his interest in science to the fullest degree.

After leaving Cambridge in 1735 Cavendish took up residence in London, although he appears to have travelled on the Continent about this time with his brother Frederick.

As regards Cavendish's scientific work, he was one of a trio of British scientists who were to take up Boyle's call, made a century earlier, to search by observation and experiment in order to find what substances were elements; meaning a substance which cannot be split up into two or more different components.

Dr. Joseph Black, one of this famous trio, discovered the gas now known as carbon dioxide, which he called "fixed air", Dr. Joseph Priestley discovered oxygen which he called dephlogisticated air, and Henry Cavendish showed that inflammable

air and fixed air were totally different from each other and from common air.

Cavendish was also one of the first men to realise the importance of measurement in scientific work. In his experiments with air he weighed balloons filled with fixed air (carbon dioxide) against others filled with inflammable air (hydrogen).

From these measurements he found that inflammable air

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was only one-eleventh of the weight of the same volume of common air, and that fixed air was more than one and a half times as heavy.

Dr. Priestley, using a machine for making sparks, had succeeded in sending a spark through a mixture of inflammable air and common air, and found that a kind of dew formed on the walls of the containing vessel. Cavendish repeated this

experiment on a vastly larger scale, using oxygen instead of common air. He then tested the dew which formed and came to the decision that this was pure water. He showed that water was not the simple substance as was so universally believed, but was composed of two substances, hydrogen and oxygen.

Besides his chemical experiments Cavendish was also interested in electricity, and in this branch of science measured electrical quantities, defined "electrical capacity" and "degree of electrification", made condensers and determined the conducting powers of various substances.

His condensers were flat slabs of glass coated with tinfoil sheets at the side to act as the two conductors. The tinfoil on the upper side of the glass was insulated, and that on the lower side the conductor connected to earth.

In his experiments on the conducting powers of substances Cavendish connected the knob of a Leyden jar to one end of the substance under investigation and holding the other end in his hand, discharged the jar by touching the outside.

Comparison of conductivity value was made by adjusting the lengths of material used until he decided that the same amount of shock was felt in each case. The ratio of these lengths was judged to be the power of conductivity of the substances under test.

The first public contribution to science made by Cavendish was a paper on *Factitious Airs* sent to the Royal Society in 1766. In 1783 notes of a series of experiments on heat were published showing that Cavendish had carried these out as early as February 1765.

Cavendish lived mainly at his residence at Clapham Common, but had also a town house in Bloomsbury and a Library in Soho at which he would attend in person to lend books to friends and any scientific workers who needed them. No charge was made for this library, but Cavendish insisted that everyone, including himself, entered their name and that of the book borrowed in a special volume.

His last great achievement before he died in 1810 was a series of experiments to determine the density of the earth.

Henry Cavendish was the first man who by purely inductive experiments converted oxygen and hydrogen into water and taught that water consisted of these two gases.

He died a rich man, leaving funded property amounting to £700,000; £50,000 in the bank, and canal and other estates of £8,000. Some of his instruments are still preserved in the Royal Institution and his name is commemorated by the Cavendish Physical Laboratory, Cambridge.

It was said of the twenty packets of manuscripts on mathematics and experimental electricity left by Cavendish that "they anticipated all those great facts in common electricity which were subsequently made known to the scientific world through the investigations of Coloumb and other philosophers".

SIR RICHARD ARKWRIGHT

1732–1792

FOR Richard Arkwright's parents, a struggling, hardworking couple of Preston in the County of Lancashire, the baby boy born to them in the year 1732 was just another mouth to feed, actually, the fifteenth. They were not to know that this, their youngest son, was to become a man whose inventive genius and organising ability would revolutionise a great industry, and introduce the factory system not only to Britain but to the whole civilised world.

It has often been stated, and with truth, that Arkwright's invention of the spinning-frame caused a greater upheaval in industrial life than almost any other discovery. Certainly, it roused both manufacturers and workers to violence and a lesser man than Arkwright might have given up what often must have seemed an unequal fight.

Little is known of Richard Arkwright's early life except that his parents could not afford to give him more than the scanty education offered his other brothers and sisters, and that before his school days were over he was apprenticed to a Preston barber in order not only to earn but to reduce the family circle, if only by one member.

Richard was first of all a run-about boy in the shop, at the beck and call of everyone, fetching here and carrying there. But he was keen-eyed and intelligent. He learned to dress hair and to attend to customers' wigs.

Before he was eighteen he had begun to experiment with dyes and had invented a successful dye which brought him in extra money.

When he had saved a fair sum Richard thought: "Now I will strike out for myself, there is surely money to be made in this hair dyeing business." He packed up his few belongings, together with his precious dyes, bade his master farewell and set out for Bolton, another Lancashire town.

Here Richard Arkwright set up shop as a master barber and wigmaker. Leaving his shop in the hands of trusted assistants he would travel the countryside, buying hair from poor serving-maids and farm workers and then dyeing it and making it up into wigs.

His business prospered, and the plump, talkative barber was

popular with the townspeople. Bolton was a great spinning centre for cotton and into Arkwright's shop came many whose livelihood was earned by spinning and weaving in their homes.

Naturally, in such surroundings, the barber heard talk of Hargreaves' spinning jenny, a device that did the work of thirty men but failed in that it could only spin threads for weft and could not produce those sufficiently strong to form the warp or

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longitudinal threads in the loom. Because of this, fabrics could not be made entirely of cotton, and linen threads had to be used for the warp.

Being of an inventive turn of mind Arkwright often puzzled over this matter and gradually formed the idea of constructing a new type of spinning frame. He heard of a machine made by a Birmingham man thirty years earlier which used rollers for thread spinning, and one day passing some workers who were drawing a bar of white-hot iron through two heavy

rollers, the idea came to Arkwright that here was perhaps the solution to the problem.

There then came into his life a man who was to cause him much trouble and distress. In the barber's shop mention was made of a certain clockmaker of Warrington called Kay, who it was said had once constructed an unsuccessful spinning machine to a description furnished by a Nottingham mechanic, Hayes, or "Highs".

When Arkwright had worked out his own ideas as far as he was able before actually making a model, he remembered Kay and visited him at Warrington to ask his assistance. "Would you be willing," asked Arkwright, "to bend me some wire and turn me some pieces of brass?"

The upshot of the visit was that Kay consented to make a model, Arkwright shut up his shop, and the two men set to work on the spinning-frame.

Kay was a fine workman, and the machine proved capable not only of making as many threads as that of Hargreaves' type but they were also of the desired strength. This was far more than a mere development of the old hand-wheel. It represented a new principle—that of spinning by rollers and regulating the different mechanical forces called into operation.

Arkwright's spinning-frame consisted of two pairs of rollers acting by tooth and pinion. The upper rollers were covered with leather to enable them to grip the cotton. The lower were fluted longitudinally to allow the cotton to pass through them. By one pair revolving more quickly than another the "rove" was drawn to the requisite fineness for twisting which was carried out by spindles or "flyers" set in front of each set of rollers.

Arkwright was proud of his invention and in order to prove its worth he had the machine set up in the parlour of the Free Grammar School at Preston.

But the men and women of the district who earned their living by spinning and weaving saw in Arkwright's device, as they had previously seen in Hargreaves' "jenny", a menace to their livelihood. Anger ran high. "Clear out," they yelled, "take the contrivance away or we'll smash it to atoms."

There was nothing for it but to go. Arkwright and Kay moved to Nottingham where they sought funds to enable a factory to be established. Through the kind offices of a friend, Arkwright was introduced to a stocking manufacturer named Strutt who, seeing the possibilities in the new machine, offered to advance the necessary funds and to go into partnership.

A patent was taken out in 1769 and Arkwright's first mill, driven by horses, was erected at Nottingham. Finding horse-

power too expensive, a second factory was set up at Cromford in Derbyshire, where the machinery was turned by a water-wheel.

In the years following many additional discoveries and improvements in carding, roving and spinning were made by Arkwright, and a fresh patent for the whole taken out in 1775.

It was said of Arkwright that no man better deserved the success that came to him, for his inventions opened up a vast new field for employment. But like other successful inventors, envied by their less successful competitors, Arkwright had many detractors; lying, unscrupulous rivals who sought to deprive him of the profit and honour gained from his work.

He was involved in many lawsuits, which were brought in order to disprove the validity of his patent. Kay, his former associate, was produced in court to swear that the idea of Arkwright's invention was really that of the mechanic, Highs, and that Arkwright had passed it off as his own.

In June 1785 a verdict was actually given against Arkwright and his patent cancelled. However, his friends and business associates believed wholeheartedly that he was the originator of the invention and there seems little doubt that the testimony of Highs and Kay was falsely given.

Despite this setback Arkwright's work continued to flourish. Even the burning of one of his factories and the opposition of manufacturers did not deter him. Gradually, men came to realise that the new machines meant more and not less work. His fortune grew and he actually planned to make enough money to pay off England's National Debt!

Arkwright amassed over £500,000, built himself a castle in Derbyshire and became High Sheriff of the County. Men admired and respected him, and in 1786 he was honoured by a knighthood from King George III.

Although he had devoted his entire life to hard work Arkwright was never a robust man and suffered greatly from asthma. In 1792 he was taken seriously ill at his Greenford Works, and died at Cromford at the age of sixty.

JOSEPH PRIESTLEY

1733–1804

Of all the notable British names connected with the discovery of the true meaning of burning or combustion that of Dr. Joseph Priestley ranks high. An English Nonconformist divine, Priestley was a fine linguist and scholar. He not only preached but wrote numerous books, taught in school and made many extremely important chemical discoveries with which his name is still associated.

To assess the value of Priestley's work it is necessary to know something of the attitude of the scientific men of his day towards combustion.

That man knew fire at least a million years ago is proved by many ancient remains, and when the savage had had time to appreciate its benefits he no doubt wondered what smoke, flame and ashes could be and why some substances burned and others did not.

The answers to his questions and those of his successors were the foundation of modern chemistry. Many ingenious explanations had been advanced through the centuries but it was not until the beginning of the modern scientific method that anything approaching the truth was reached.

One of the first of the modern experimenters, Stahl, early in the 18th century put forward the famous "phlogiston theory" which, briefly, laid down that when combustible bodies burned they lost "something", and this "something" became known as phlogiston, which it was claimed was not fire itself but the material of fire. All combustible materials, according to Stahl, including metals, contained phlogiston; non-combustible substances contained no phlogiston.

Like other scientists of his day Priestley believed this theory and, in spite of his later discoveries, remained a confirmed phlogistonist to the end of his life.

The background to Priestley's career was one of strong nonconformist principles. His father was a poor woollen-cloth dresser of the West Riding of Yorkshire who was hard put to it to keep a home together. When his mother died, Joseph, then only six years old, was adopted by an aunt and left his father's house.

When he entered school the boy's ability to learn was soon

evident. His progress in the classics was rapid and in holiday time to amuse himself he studied Hebrew, French, Italian and German.

At sixteen, however, his health suddenly deteriorated and between the ages of sixteen and twenty he was compelled to study at home.

From early years Priestley had been brought up with the

JOSEPH PRIESTLEY

idea of entering the ministry. He acquiesced in this training and was subsequently given charge of a small chapel. But he had little real interest in the work and it was not long before he turned his attention to teaching instead.

It was in 1761, when a classical tutor in a nonconformist academy at Warrington, that he met and married the daughter of an iron-master. Shortly after this he met Benjamin Franklin, the American scientist, and at the latter's instigation Priestley carried out many experiments in electricity.

His *History of Electricity* was published in 1766 and he became a Fellow of the Royal Society. For a brief period at this time Priestley again took charge of a chapel, but relinquished this after a short time in order to become librarian to the Earl of Shaftesbury.

It was while living next door to a brewery that Priestley first experimented with fixed air, and made soda-water by forcing the air into water.

This was the beginning of his work on different kinds of airs, as gases were then called, and his name became famous for the apparatus he devised with which to carry out his experiments.

By means of what he called a "pneumatic trough" he perfected a method of collecting a gas by bubbling it into an inverted jar, placed in a trough of mercury or water. He worked also at making new "airs" by mixing metals with certain acids, and producing other acids by heating various substances very strongly.

As a result of these and many other experiments Priestley was successful in obtaining several new gases. These were oxides of nitrogen, "hydrogen-chloride", sulphur dioxide, silicon fluoride, nitrous oxide and ammonia. In all, he discovered nine gases of which three species only had been recognised before he began his researches.

Most famous of all his discoveries was the gas, called by Priestley "dephlogisticated air", and now known as oxygen.

The experiment was made by heating certain substances by means of a large magnifying glass which focused the sun's rays on them through the glass; the substance being in a bottle of mercury inverted in a trough of the liquid.

One of his materials was the red powder obtained by heating mercury in air, known as Red Mercury Calx, and Priestley found that a gas was emitted by this substance. He collected the gas in jars and examined it. He found that a candle burned brightly in it, that a piece of glowing wood flamed up and then burned away, and that a live mouse put inside the vessel lived twice as long as in a jar of ordinary air. Finally, he breathed it himself and stated "my breast felt light and easy for some time afterwards".

Holding as he did to the phlogiston theory, Priestley explained the results of his own work by claiming that the substance burned quickly in his new air because it contained no phlogiston itself and consequently took the phlogiston of the burning substance. In brief, the new gas was common air without phlogiston, i.e., "dephlogisticated air".

Although led astray by the phlogiston theory Priestley's discovery was of great importance, for it blazed a trail for future experiments which established the real nature of combustion.

He also experimented with a machine for producing electric sparks and by this means was instrumental in assisting Cavendish to determine the nature of ordinary water.

Through his many chemical discoveries and experiments Priestley's name and fame were high in the esteem of contemporary scientists, but in 1780 an unfortunate occurrence in Birmingham led to his sudden departure from England for America.

Due to a mistake, his name was advertised as one of the promoters of a public dinner in Birmingham, to celebrate the fall of the Bastille. Popular feeling ran high against this banquet and Priestley was warned not to attend. He took heed of the warning, although he was in no way connected with the arrangements of this affair, but on the night of the dinner, while at a friend's house, a Birmingham mob fired Priestley's home and destroyed most of his papers and possessions.

Although compensated to some extent for this disgraceful attack, Priestley and his family left for the United States shortly afterwards and he remained there until his death in 1804.

A fearless speaker and a man of great intelligence, Joseph Priestley held certain unorthodox views which made him unpopular with many Nonconformists, but in the world of science he had a host of admirers and friends.

His was the true imagination of the scientist and thinker, and in his laboratory he found solace and recreation from his theological studies.

He was a voluminous writer on religious, historical and scientific matters, a man of strong home ties and affections, and towards the end of his life his great wish was to return to his own country where the best of his life's work had been carried out.

JAMES WATT

1736–1819

THE 19th century was the age of steam power, and the development and perfecting of the steam engine signalised the beginning of the Industrial Revolution.

Without the story of James Watt, one of Britain's great mechanical geniuses, no true account of the steam engine is possible, and any description of Watt's work must also include the earlier stages of the use of steam power.

By the end of the 17th century, men were experimenting with steam. In 1690 a Frenchman, Denis Papin, found that steam could develop great power, and created in a metal cylinder enough steam to move a piston which, by condensing the steam, was brought back again to its original position.

Captain Savery, an Englishman, improved Papin's design and patented a pump in 1698 for use in draining coal mines of water. However, before his pump was actually produced, Savery got in touch with an iron-worker, Thomas Newcomen, who had also been experimenting along similar lines, and after some years Newcomen made a rough, but fairly efficient pump.

It was by his development of the Newcomen pump that James Watt became famous as the inventor of the condensing steam engine.

Born in 1736, Watt was son of a Greenock shipowner and merchant who was also a maker of nautical and surveying instruments and a man greatly respected by his fellow townsmen.

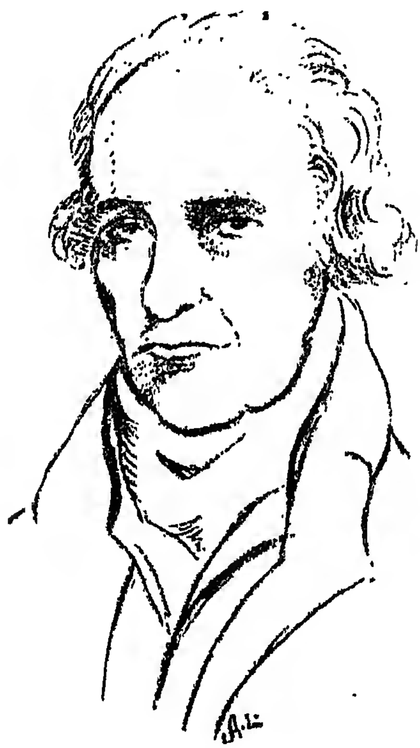
Young Jamie was a sickly child, too delicate to do much hard work or take part in the rough games of his schoolmates. In the early days at Greenock School his master would shake his head sadly and say: "Puir bairn, he's a dull lad, a dull lad."

But the boy had one great delight. His father let him have a forge of his own and each evening when lessons were done Jamie would hammer away at his anvil, learning how to make and repair instruments, until at length he came to have a fine skill.

When he was eighteen James left Greenock and travelled to Glasgow, twenty miles distant, to try to get work in an instrument maker's shop so that he might perfect himself in his chosen profession.

But Glasgow was devoid of any such business and he was obliged to take a post with an optician.

A year passed, then with a couple of guineas in his pocket James Watt set out to seek his fortune in London. After some vicissitudes he was taken on by an instrument maker in Cornhill. All might have gone well had not the city air disagreed with the young Scot so that he became weak and ill, and after a year had to return to Scotland.



JAMES WATT

Watt then decided to open a shop of his own in Glasgow, but here he met opposition, for the Guilds refused him permission owing to his not having completed his apprenticeship.

There was nothing for it but to drop his plan, so he set up as a repairer and maker of instruments to Glasgow University with a workshop within the University precincts.

Two years passed, during which time James Watt established himself as a capable and conscientious workman. When he

was twenty-three he again travelled to London where he bought all the equipment he could afford in order to try once again to set up his own business.

Back again to Glasgow he went. This time there was no question of his position and he opened a shop in the city as seller of "All Sorts of Mathematical and Musical Instruments".

Then he got his great chance. Professor John Anderson of the University looked in one morning to ask if James would overhaul an engine for him. "The old Newcomen pump," he explained, "that goes by steam."

Although rather out of his line Watt promised to do what he could, and when the engine was brought he studied the crudely designed apparatus closely to find out what was at fault.

The engine had been designed to work a pump for pumping water out of mines. The suction pump rod was attached to a weight at one end of a lever, the other end being connected to a piston which moved up and down in a cylinder.

The weight kept the piston at the top of the cylinder, but when steam from a boiler passed into the cylinder under the piston the steam was condensed by cold water from a jet, thereby causing a vacuum beneath the piston which was pushed down by atmospheric pressure to the bottom of the cylinder. This piston movement worked the lever and caused the up-stroke of the suction pump.

Adjustment of boiler steam and water flow was all that was necessary to bring about the up and down strokes.

After detailed examination Watt discovered that the coal consumption needed to produce sufficient steam was greatly in excess of the heat gained, for no sooner did the hot steam enter than it gave up its heat to the cold cylinder.

It was abundantly clear that some method was required whereby the steam could be forced to enter a vessel, emptied of air and always cold, where it would condense without at the same time cooling the cylinder.

Watt repaired some trifling defect of the engine for the Professor, but determined to try to make a more efficient model himself.

He experimented for several years and finally decided on a separate chamber for condensing steam (now known as a condenser). To keep the cylinder hot he surrounded it with non-conducting material and instead of leaving its upper end open he closed it entirely.

Watt's main principles were covered by three patents taken out in 1769, 1781 and 1782. They were, first, to keep the cylinder as hot as the steam which enters it; secondly, conden-

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sation to take place in a separate vessel connected to the cylinder through a pipe or valve, and thirdly, to employ steam pressure to impel the piston.

To carry out his experiments, Watt, who never had much spare cash, borrowed from a kindly friend, Dr. Roebuck, and in exchange signed away to the Doctor two-thirds of all rights in the pump.

Luckily for Watt, Dr. Roebuck, in turn, owed a sum of £1,200 to a Mr. Matthew Boulton, founder of the Soho Engineering Works near Birmingham. To Boulton, Roebuck offered as payment of his debt the share in Watt's new pump. Boulton, a keen business man, asked to see the pump and soon discovered that it was likely to be a money-maker. He already knew Watt as a skilful worker, and after an interview Boulton offered him a partnership in his firm, to be known thereafter as Boulton and Watt.

Watt could hardly believe his good fortune. He was tired of the shop and had despaired of ever getting out of the rut. Now everything was changed. The partnership was established in 1774 and for twenty-five years he and Boulton worked together in harmony making their firm world-famous. The Watt engine was used all over Britain to drive machinery, as well as in the field of transport.

In 1800 the two partners retired from active business leaving their sons to carry on the work. Watt had a country estate at Heathfield Hill, near Birmingham, and there he lived and devoted himself to experiments and invention.

One of his later inventions was an apparatus which enabled him to copy sculpture with great accuracy, and among many others were ideas for copying letters, bleaching cloth, and the prevention of smoke from factory chimneys.

Through his long life Watt made many scientific friends, Joseph Priestley, Joseph Black and Wedgwood were amongst these. Up to the last hour of his death on 19th August, 1819, he kept his mental faculties alert, and died with his keen brain unimpaired.

EDWARD JENNER

1749–1823

DURING the past hundred and fifty years there have been many great advances in medical science. Amongst these the discovery of vaccination, which brought about so radical a change in medical practice, was one of the most far-reaching importance for the whole world.

Up to the end of the 18th century smallpox was one of the most dreaded diseases of mankind. Of those who contracted it the majority succumbed, and those who struggled back to life were often blinded and always terribly disfigured.

To combat this "plague" it was common practice to inoculate any who wished with smallpox virus obtained from patients suffering from a mild attack of the disease, a partially useful but dangerous proceeding introduced into England from the East in 1721.

It was an English physician, Edward Jenner, who superseded this inoculation process by a system of vaccination which was to spread over the world in the short space of six years and deliver humanity from one of its worst disorders.

Jenner was born in Berkeley, Gloucestershire, on 17th May, 1749, third son of the Rev. Stephen Jenner, Vicar of that Parish.

His childhood was uneventful. When he was six his father died, and Edward came under the care of his eldest brother, Stephen.

Schooldays were spent first at Wotton-under-Edge and then at Cirencester. Like most boys Edward Jenner had various hobbies. In his case it was the collection of fossils and natural history specimens that interested him most. Interests that he never lost.

He early resolved to become a surgeon. His family gave consent and when he left school he was apprenticed to a surgeon at Sodbury, near Bristol.

His great chance came when, at the age of twenty-one, he went to London to become pupil of the well-known surgeon John Hunter, in whose house he lived for two years. Hunter became Edward Jenner's friend and teacher during the time the young man was in his care and imbued him with the spirit of scientific investigation that was to stand him in such good stead.

While working in London Jenner was asked to prepare certain specimens brought home in 1771 from Captain Cook's expedition, and later received an offer of the post of naturalist on a second voyage which was to be undertaken.

The offer was very tempting, but Jenner's desire to practise medicine was stronger still. He declined the post and in 1773 returned to Berkeley to start his professional career.

EDWARD JENNER

Few could refrain from liking the young doctor. His manners were friendly and easy, his kindness to poor patients proverbial and his work for the sick untiring.

Every day he might be seen riding off on his rounds wearing a blue coat, black top-boots and silver spurs. Jenner was rather a dandy and was never seen in the rusty, fusty garments worn by so many country physicians.

With the country gentry too he was a popular figure. He was an accomplished musician and in his leisure hours was known to compose tolerably good verse. He helped also to found a

local medical society and in 1788 constructed the first balloon seen in that part of the country.

Like other medical men of his time Jenner knew of the practice of inoculation of smallpox virus, carried out by practitioners whose entire income came from this specialised work. But as he rode the Gloucestershire lanes he would ponder over what he saw and heard concerning smallpox and that other disease known as cowpox which was so prevalent in many of the dairy herds. He had heard of, and indeed frequently met and talked with milkmaids who suffered from cowpox caught from the animals they tended, and who, strangely enough, never seemed to fall victims to smallpox.

It was, as a matter of fact, an old country belief that by some mysterious process of nature milkmaids who had had cowpox were immune from smallpox.

For many years while carrying out his medical duties Jenner investigated, tested and recorded cases of cowpox and smallpox. In 1788 he was elected a Fellow of the Royal Society, and in 1792 took his degree of M.D. from St. Andrew's University.

By 1796 he was convinced that his conclusions were correct, and he proposed to make a scientific vaccination in public and let the results be known.

On 14th May of the same year, a small boy, James Phipps, helped Jenner make medical history. He was vaccinated with lymph taken from the vesicles of cowpox pustules on a woman's hand. The lad had a mild attack of cowpox and on 1st July following he was vaccinated with variolous matter from a case of smallpox. No smallpox followed, Jenner's conclusion that cowpox had protective power against smallpox was vindicated.

It was some time before this test could be repeated as cowpox disappeared from the dairies in the district. But finally, after other successful experiments, Jenner went to London, where he waited three months before he could find anyone who would consent to be vaccinated. At last he found a patient, and after successful treatment he published a full account of his observations and conclusions in a short treatise, now a classic in medical works. With coloured plates and descriptions of twenty-three cases, the most important statement was "that the cowpox protects the human constitution from the infection of smallpox".

Jenner's reputation was established. He was then begged to stay in London and make his discovery more widely known, but preferred to return again to Berkeley and continue there with his experiments.

At first there was a good deal of opposition to Jenner's work. Many medical men, notoriously averse to change, reserved their

judgment, and those whose living was derived from smallpox inoculation declared that Jenner's practice was not only useless but dangerous.

But the facts spoke for themselves. Vaccination gained ground and from Britain spread to the Continent. In 1806 Spain actually sent an expedition for the purpose of "diffusing cowpox throughout the Spanish possessions in the Old and New Worlds".

In Geneva and in Holland preachers besought their congregations to be vaccinated; in Germany, for many years, the anniversary of Jenner's experiment on the boy Phipps, was celebrated as a feast day, and in Sicily, Naples and South America, religious groups were formed for the purpose of arranging for vaccination.

The Royal Jennerian Society was established in London in 1803, later to be replaced by the Government's National Vaccination Institution set up in 1808. Honours were showered upon Edward Jenner. Thousands blessed his name, and he was elected a member of most of the continental scientific societies.

Jenner, who had spent much of his own money on his experiments, petitioned Parliament for a grant, and in 1802 was given a sum of £10,000 by the Government. Four years later a further grant of £20,000 was voted to him for his work.

So great a benefactor to the world was Jenner considered that when he requested Napoleon for the release of two British prisoners of war, held after the sudden termination of the Peace of Amiens, it is stated that the Emperor hearing his name declared "The great doctor Jenner! We can refuse him nothing!"

When Edward Jenner died in 1823 he was happy in the knowledge that his untiring work for science had brought health to millions of his fellow men. He was blessed with a good wife and peaceful home surroundings, and of him it was truly said that "he was in the first rank of those who have improved the art of medicine".

JOHN LOUDON McADAM

1756–1836

At a time when the roads of Britain were in so rough and dangerous a state that in wet weather most of them were impassable, and only when dry could wheeled vehicles use their whole breadth, there was born in Ayrshire to a Scottish banker and his wife a boy whose name was to become famous in the history of road development.

On his father's side John Loudon McAdam was descended from the clan of the McGregors, and on his mother's from the Cochranes and Earls of Dundonald.

When John was still an infant a fire broke out at Laywyne, the McAdams' home, and the baby narrowly escaped with his life. The house was destroyed and the family moved to another country estate near Straten.

It was here, while still a lad, that John McAdam gave the first signs of his skill at road planning. The roads all over Britain were in such an appalling state that a stage-coach took fourteen days to travel from London to Edinburgh. Tramping to the village school summer and winter the boy first grumbled at the mud and ruts and then, being an intelligent lad, wondered why nothing was done to remedy their serious disadvantages.

Day after day he thought over the matter until at length he planned and constructed a model section of the road between Maybole where his school lay, and his own home. Unfortunately, in spite of John's designs, the road remained in its disastrous state.

But John McAdam was not to stay long in Scotland. When he was fourteen his father died and he was sent to New York to live with a banker uncle.

In the New World the young Scot fared well. He had the native caution of his land, but on the other hand was quick to make the best possible use of any opportunity that presented itself.

John McAdam stayed in the United States until the end of the revolutionary war and made for himself a substantial fortune working as an agent for "the sale of prizes".

At the back of his mind, however, there was always the desire to return home and in 1783, with his American wife,

he went back to Scotland, where he bought an estate at Sauhric in Ayrshire.

There he settled down and devoted himself to local affairs, in due course becoming a magistrate, deputy lieutenant for the county, and a road trustee.

It was then that McAdam's genius for roadmaking made itself evident. As a road trustee he knew that the state of the

JOHN LOUDON McADAM

roads was not only a disgrace to the country, but a severe check to commerce. With typical Scottish determination he set to work to experiment with improved methods of construction.

Some idea of the British road system in the early 18th century may be gathered when one learns that not one new road was built between the 7th and 14th centuries, and that in McAdam's time the old Roman roads, constructed under

such vastly different social conditions, still remained in use as main highways.

Briefly, the Romans made use of the old trackways, using the original earth foundations and building on these four layers of stones mixed with mortar, lime or chalk, and gravel.

The ideal to which McAdam worked was, in his own words: "To build an artificial flooring forming a strong, smooth solid surface at once capable of carrying a great weight and over which carriages may pass without meeting any impediment." It was his intention to construct roads suitable to the traffic that they were to carry.

At his own expense he carried out many tests in face of local opposition, and when he left Sauhrie to take an appointment as revictualling agent for the Royal Navy in the western ports of Britain, he continued his experiments at Falmouth, South Devon.

Here he finally reached the conclusion of his tests. His method was to construct roads raised slightly above the ground on either side, having drains dug on each side of the track. The road surface was then covered by layers of stone, broken into angular pieces, as nearly of one size as possible, and not weighing more than six ounces.

It was McAdam's contention that with passing traffic the stones would gradually fit into place like the bits of a jig-saw puzzle, and the road would then be consolidated and impervious to water. Granite, greenstone and basalt were the suggested materials, but eventually basalt was discarded.

In 1815 McAdam was appointed Surveyor General of Bristol roads and at once began to put his ideas into practice. His first published work, a pamphlet entitled *A Practical Essay on the Scientific Repair and Preservation of Roads*, brought him before the public notice, and by the time his second work *The Present State of Roadmaking* had run through five editions the success of his system was being widely recognised. The question soon became "How soon could all the roads be macadamised?"

McAdam gave evidence before the House of Commons Committee set up to enquire into the whole problem of road construction and maintenance, and during the course of this enquiry it transpired that he had travelled over more than 30,000 miles of British roads, had spent £5,000 from his own purse, and devoted 2,000 days to the task.

So impressed was the Committee with McAdam's knowledge and skill that in 1827 he was made Surveyor General of Roads, reimbursed for his expenses, granted a gratuity of £2,000 and offered a knighthood, which latter honour he declined.

McAdam spent his holidays each year in his beloved Scotland and he died there at the age of eighty-one on the 26th November, 1836.

He was a generous, warmhearted man, a well-loved friend, a lucid writer, and throughout his life interested in scientific research.

He had the good fortune to see his methods of roadmaking adopted in many parts of the civilised world. Thanks to his improvements, there was built up in Britain a network of mail-coach connections which proved of great commercial value as well as the foundation of the railway system that was to follow.

THOMAS ROBERT MALTHUS

1766–1824

In England, in the year 1793, a book entitled *An Enquiry Concerning Political Justice*, etc., written by the ardent radical, William Godwin, was being widely read and discussed.

Godwin, a man passionately interested in sociological problems, advanced a theory of human perfectability to be reached by the equalisation of wealth. His belief was that if once the public conscience was awakened by the power of truth, after calm reasoned discussion no government would be necessary, and such things as crime, war, vice, disease and misery would disappear. Man would seek only after good.

The book was an instant success. Young and brilliant men like Shelley, Wordsworth and Coleridge were influenced by it and proclaimed their belief in its teaching. Godwin was acclaimed on all sides.

There was, however, a certain young minister, Robert Malthus, who, himself of no mean intelligence, had read and re-read Godwin's book with more sternly critical eye.

There appeared to this young man a false assumption, a lack of historical knowledge in this greatly lauded publication. He asserted his views to his father, also a man of excellent education, and so clearly did he put his case and so brilliant were his arguments that the elder Malthus at length persuaded the son to put his ideas into written form.

Thus was born the now famous Essay on *The Principle of Population As It Affects Future Improvement of Society*, which was to fall like a bombshell into a society which looked on growth of population as a sign of prosperity and had no wish to be forced to reconsider some of its most cherished beliefs.

What was the background of the writer of the Essay? He was the second son of an intelligent country gentleman of moderate fortune, Daniel Malthus, a friend and executor of Rousseau, and a man who happened to have had rather peculiar views as to the education of his boy, who he considered showed considerable brilliance.

Robert was not sent to school, but was taught first by his father, and then by two remarkable men, Richard Graves, author of *The Spiritual Don Quixote*, and the classical scholar Gilbert Wakefield.

At eighteen, Robert Malthus entered Jesus College, Cambridge. He was a virile, energetic young man, extremely amiable in disposition, and of an engaging candour, despite an unfortunate defect in speech. At college he read history, poetry, and modern languages, won prizes for Latin and Greek and was ninth wrangler in the mathematical tripos. He took his M.A. degree and by 1788 was in holy orders.

THOMAS ROBERT MALTHUS

Malthus had the analytical mind of the scientist and was continually engaged in long discussions with his father. Politically, he was a Whig, and his theological leanings were of the Paley type.

The first indications of Robert Malthus's interest in human problems were embodied in a pamphlet entitled *Crisis* which he wrote in 1796, and in which he attacked Pitt, from the Whig viewpoint, for his support of the Poor Law schemes then under consideration. In deference to his father's wishes, however, this pamphlet was not published, and it was not until two years later that he startled society with his Essay.

The first edition consisted of some 50,000 words divided into nineteen chapters. The kernel of the work, as it were, lay in the claim that firstly, food is necessary to the existence of man, and secondly, that passion between the sexes is also necessary and that it will continue to remain nearly in its present state. Malthus scorned Godwin's theory that restraints might one day not be needed in a perfect human society. From his first postu-

lations he proceeded to lay down the principle that population, if unchecked, increases in geometrical, and subsistence increases only in an arithmetical ratio.

It was beyond the bounds of possibility, Malthus considered, that a human society could exist in peace and leisure, increasing in numbers and not taking heed to the provision of food for themselves or their families.

Perhaps because his statements were unanswerable, Malthus was at once vehemently attacked. Godwin's friends were most bitter; men like Cobbett and Hazlitt were ranged against him. He was denounced as advocating war and crime. It was said that he had no use for charity, that even marriage was not sacred to him.

In face of this turmoil Malthus stood firm. It is a fact that Prime Minister William Pitt dropped his Poor Law Bill two years later on the grounds that he had done so in view of certain opinions, and no less important was the conversion of Archdeacon Paley, who became one of Malthus's firm adherents.

Quite undaunted by his detractors, Malthus, who was determined to pursue his studies, travelled on the Continent in order to gather more data for his work.

In 1803 he published the second edition of his Essay which, while adhering to the main principle, contained the results of his latest investigations. This second work is a lengthy, almost sombre document, the important modification in it is the recognition that in addition to the positive checks of war, disease, and other human ills, there may be the check of moral restraint by which Malthus meant the postponement of the marriage age and strict sexual continence.

He saw, crystal-clear, the absolutely inescapable fact that human society, whether socialist, communist, fascist, or of any other political bias, is enormously fertile, and that its reproductive power is strong under all conditions, in all places and climates.

Where he failed, as we see it to-day, was in his inability to foresee the curve of the future. He did not visualise the development of transport facilities, or the vast colonisation schemes, both of which so greatly increased the opportunities for obtaining foodstuffs and raw materials. Malthus was no advocate of birth control, his check was moral restraint. But contraceptives and raising of the marriage age, due to higher standards of living, have cut the birth rate in Western countries to an extent that he never even contemplated.

The whole of his life was devoted by Malthus to research. He married in 1804 and the following year was appointed

professor of History and Political Economy at the East India Company's college at Haileybury. He was a Fellow of the Royal Society, Member of the French Institute, and one of the five foreign associates of the Academie des Sciences Morales et Politiques, and a member of the Academy of Berlin.

Malthus died suddenly in 1834 after seeing his Essay run through six editions, each of which was amplified by results from his most recent investigations.

In the first half of the 19th century his views influenced public opinion, but later became out of date. To-day, nearly one hundred and fifty years after the Essay was first published we are faced with the nightmare of starving populations and world-wide food shortages. The "checks" of plague, pestilence and famine are to be seen everywhere. What would be the reaction of this great English thinker and scientist to the problems we have now to solve?

JOHN DALTON

1766–1844

THE theory of the atomic structure of matter originated with the ancient Greeks many centuries ago, before 570 B.C. Throughout the ages many links were forged in the chain of knowledge, until at the end of the 18th century advances in chemical analysis were made by which it was possible to determine the proportions of the different elements present in simple substances. The old atomic theory held by the Greeks had been renewed in the 17th century by the Hon. Robert Boyle and other British scientists. It remained for an English chemist and natural philosopher, John Dalton, to put forward one of the greatest and most far-reaching scientific theories ever presented to the world.

Dalton came from a family of artisans. He was second son of a poor weaver and first saw the light of day in a thatched cottage at Cockermouth in the County of Cumberland in the year 1766.

His parents were Quakers and the boy received his schooling at a local Quaker school where he distinguished himself from his fellows by his studious ways. To learn and learn and learn was always John Dalton's ambition.

But what had a poor lad to do with books? At ten he had to go to work and entered the service of a well-to-do Quaker named Robinson. Observing the boy's love of study, his master, who had some scientific attainments, gave John Dalton daily lessons in mathematics and encouraged him to read all he could.

When he was twelve John went to teach in the village school, and at fifteen he left to live in the neighbouring hamlet of Kendal where he joined a cousin who was the local schoolmaster.

Not long after this the cousin retired and with one of his brothers John took over the running of the school. But although both the Daltons were hard workers and gave of their best, the school was never popular. Perhaps it was that their manners were awkward and their speech rough, for in some way they failed to endear themselves to their pupils.

It was, however, during these years of humdrum life that John Dalton was able to study to his heart's content and make a

life-long friend of the blind philosopher, John Gough, a man who later did so much to help him in his scientific career.

Gough was an ardent meteorologist and imbued his young friend with enthusiasm for the observation of natural events. It was due to Gough's advice that Dalton started the meteorological diary which he kept for fifty-seven years.

When he was twenty-eight years old Dalton got the chance

JOHN DALTON

of advancement for which he had worked so diligently. Through Gough's kindly help he applied for and was appointed to the post of teacher of mathematics and natural philosophy in the Academy of Manchester. The year following he was elected a member of the Manchester Literary and Philosophical Society.

It is interesting to note that just before his appointment to the Academy Dalton discovered, through his botanical studies, that he suffered from colour blindness, a defect also shared by his brother. In order to learn more about this Dalton lectured

and wrote of his observations and for many years this physical peculiarity was known as "Daltonism".

Dalton's life was bound up almost entirely with his teaching, lecturing and laboratory work in Manchester. Social amusements held no interest for him; he always declared that he was far too busy to marry, it was his work that was nearest and dearest to his heart.

In his sober Quaker dress, the grey, neatly folded stock and dark knee breeches, black buckled shoes and broad-brimmed beaver hat, John Dalton became a familiar and revered figure in Manchester life.

To persistent enquirers his manner was often brusque, and his almost invariable answer regarding scientific matters was: "I have written a book on that subject and if you wish to inform yourself about it you can buy my book for three shillings and sixpence."

It was in 1808 that he published the results of his chemical investigations under the title of *A New System of Chemical Philosophy* and the whole scientific world acclaimed his work.

Following on the work of Robert Boyle and Newton, Dalton arrived at four simple conclusions which were briefly: that atoms are really separate material particles which cannot be subdivided by any known chemical process; that atoms of the same element are similar to one another in all respects and equal in weight; that atoms of different elements have different properties, weight and affinity, and that compounds are formed by the union of atoms of different elements in simple numerical proportions.

Not only did Dalton stress his belief that atoms of different chemical elements differed from each other, he also claimed that they possessed different weights. In 1803, prior to the publication of his book, he read a paper to the Manchester Society regarding his investigations into the relative atomic weights, and although many of the weights originally given by Dalton are now known to be inaccurate, yet his findings represented the first table of atomic weights ever drawn up.

Dalton received many honours in his lifetime from learned and scientific societies. The Royal Society, of which he was a member, conferred on him its first Royal Medal. He visited foreign capitals and talked with scientists from all over the world, but to the end his interest lay almost completely in his work in Manchester.

Even towards the end of his life when he knew his power was failing he still held rigidly to his routine although he often

found the effort of carrying out an experiment too much for his strength.

On 27th July, 1844, he had a stroke and the next day passed quietly away. The world paid homage to a great scientist. More than forty thousand people filed past his coffin while it stood in Manchester Town Hall. He was buried in Ardwick Cemetery near to the city and townsfolk he loved and served.

John Dalton's work laid the foundations for the development of the Atomic Age in which we live to-day. In the words of another great British scientist, Sir Humphry Davy: "Dalton's permanent reputation will rest upon his having discovered a simple principle universally applicable to the facts of chemistry in fixing the proportions in which bodies combine, and thus laying the foundation for future labours respecting the sublime and transcendental parts of the science of corpuscular motion."

RICHARD TREVITHICK

1771–1833

MECHANICAL engineering developed with great rapidity after the creation of the steam engine by the British inventor James Watt at the end of the 18th century. The age of railways and steamships followed, and it was to another Briton, a Cornish engineer, Richard Trevithick, that the honour goes of being the first to use a steam carriage on a railway.

A locomotive had been built in France in 1769 but had never been put to practical use, and in Britain Watt and Murdoch made a small model nearly twenty years later. But Trevithick's was the first steam engine to be tried out by the public when it appeared on the road in 1804.

One of the most prolific inventive geniuses that Britain ever produced, Richard Trevithick, only son of a hardworking colliery manager, was born in April 1771 in the parish of Illogan in the county of Cornwall.

During boyhood, Dick Trevithick grew up among miners and engineers; he heard on all sides discussion and argument as to the merits of this or that school of engineering. In 1771 the Soho Engineering Co., Boulton's and Watt's firm, set up in Cornwall to the great disgust of the local men, and Watt's assistant Murdoch lived at Redruth close to the Trevithick house.

Dick was a bright and intelligent lad, but he had little use for schooling; mining was in his blood. Whenever he got a chance he played truant and spent his time hanging about the mines talking to the men and watching the engines working.

His master could do nothing with him and, indeed, Dick's quickness at figures irritated rather than pleased the teacher, who resented the fact that his pupil could do six sums correctly before he had finished one.

As he grew to manhood Trevithick developed an almost herculean strength. With his rough locks flowing and his powerful frame he strode the streets of the little Cornish town like one of the giants of old. He became the finest wrestler in the county and it was said that he could lift a fifty-pound weight attached to his thumb above his head and then write his name on a wall.

No one could keep Dick away from the mines. The engineers

were interested in the lad's ability to absorb what he was told, and when he left school he had no difficulty in getting work with a local firm near his home where he was able to tend his beloved engines from morning to night.

As early as 1796 he had made model pumps, and in 1797 he produced his first invention of any importance, an improved plunger pole pump for direct mining. This pump was far

RICHARD TREVITHICK

more satisfactory than others in use and was capable of bringing up more water, but Trevithick was not satisfied. "It's more steam pressure we need," he would say; "without pressure how can we get more power."

In 1800, while still working in Cornwall, he built a carriage with a high-pressure, non-condensing steam engine, and elated with his success at Christmas time, 1801, he invited some of his friends to take the first trip with him.

Although they laughed and joked about the strange contraption, engineering history was made that Christmas Eve, when

the first load of passengers ever carried by steam, started upon their memorable journey.

The engine bumped and puffed over the rough Cornish road. The passengers hung on for dear life, their legs dangling down on each side. All went well until a slight hill was reached, then the wheels suddenly refused to turn, the engine gasped and stopped. It would go no further.

Amid jeers and cheers the travellers climbed down. But Dick Trevithick was not downhearted. "Not so bad," he said, "but I'll build another that will go much faster and much farther."

Next year he applied for a patent for a steam engine for propelling carriages and travelled to London to try to interest Count Rumford and Sir Humphry Davy in his invention.

Determined to show Londoners what Cornishmen could do, Trevithick actually drove his engine through the streets from Leather Lane in Holborn along Oxford Street to Paddington. This created great interest for the citizens of London and so encouraged Trevithick that he gave another public demonstration the following year when his "locomotive" drew five carriages and seventy passengers at the terrific speed of five miles an hour!

After nine miles the engine came to a full stop and the tourists had to get home again as best they could. But all felt that they had had their money's worth.

For five years more Trevithick worked hard at his designs. In 1808 he went again to London, found some open ground near Euston Square, and there laid down a circular iron track, and advertised five shilling trips on his engine.

Round and round this track were carried the astonished Londoners at fifteen miles an hour, bets were taken by sportsmen on the speed, and Dick Trevithick became quite a popular figure.

The Board of Trinity House contracted him to lift ballast from the bottom of the Thames, and he was also consulted regarding a scheme for building an archway under the river. It had always been one of Trevithick's theories that it would be possible to dig a tunnel under the Thames and then drive an engine through it.

Besides being the first man to prove that wheels would adhere sufficiently strongly to rails for purposes of traction on lines of ordinary gradient, Trevithick, in many ways, influenced the construction of steamboats and was a pioneer in his schemes for using iron to build large ships. He obtained a heavy, old canal barge, put one of his engines in it and moved it by steam,

and he suggested that a screw propeller set at the stern of a vessel could be turned by steam to push the ship.

Trevithick was also the first man to apply steam to agriculture, and a high pressure threshing machine was built by him in 1812. He always claimed that every process in agriculture might be formed by steam and that the use of the steam engine would double the population of the kingdom and make British markets the cheapest in the world.

When he was forty-five Trevithick travelled to Peru to superintend setting up some of his engines in Peruvian copper and silver mines. From Peru he went south to Chile and thence to Costa Rica where he engaged in more mine work. After many troubles and hardships and the loss of most of his money, Dick Trevithick returned to England after an absence of eleven years.

It is no credit to Britain that Trevithick, one of the greatest mechanical benefactors of his age, could obtain no monetary award for his inventions, and that he was allowed to die after six years of poverty so destitute that only the efforts of workmates in Dartford rescued him from a pauper's grave.

Trevithick was a man of great courage and engineering ability, but he had no head for business and never obtained money or backing to further many of his inventions.

He married a Cornish girl and left four sons and two daughters. A memorial window to Trevithick's memory may be seen in the north aisle of the nave of Westminster Abbey. An engineering scholarship was endowed in his name at Owens College, Manchester, and there is a Trevithick triennial medal at the Institution of Civil Engineers.

SIR HUMPHRY DAVY

1778–1829

The Davy Safety Lamp made the name of its inventor, Sir Humphry Davy, known to millions, but, in fact, this was only one of many important discoveries made by a British scientist and natural philosopher, of whom it was said that "he was not only the greatest, but one of the most benevolent of men".

Humphry Davy was born on 17th December, 1778, in the Cornish town of Penzance. His family lived on a small estate, with a modest income. Humphry was eldest of five children and spent his childhood between his parents' home and that of his mother's foster father, an eminent local physician, Mr. Tonkin.

At a local school and later at the Truro Grammar School, Humphry was remembered as a boy with a fine memory, a voracious appetite for books, and a gift for story-telling which endeared him to his schoolfellows and was later very notable when he became a lecturer.

Robert Davy, his father, died in 1794 and the following year Humphry was apprenticed to Dr. Borlase, a surgeon-apothecary of Penzance, it being the boy's intention at that time to become a doctor.

Humphry was an ungainly, rough-mannered youth whose outward appearance belied the keen intellect and imaginative genius within. He was a prolific writer of verse, and it has been stated that if he had not become a scientist he would have been a great poet. Be that as it may, he wrote good verse; that is when he was not making experiments!

He struck up a friendship with a saddler named Dunkin who was also of a scientific turn of mind and who lent Humphry some rough apparatus to carry out his work. In the attic of Mr. Tonkin's house Humphry used to shut himself in and refuse to allow anyone to interfere. There were frequent and frightening explosions, and friends said that he was a "lazy dog who cared only for his wretched experiments".

It was after reading the treaties of Nicholson and Lavoisier that Davy turned his attention to chemistry seriously. It opened up a new world to him and gradually his interest in medicine began to wane in view of this new and, to him, far more exciting study.

One day during his stay with Dr. Borlase, while idly hanging over the worthy Doctor's gate, a gentleman passing by got into conversation with him and became so interested in the ideas put forward by the rough-looking youth that he invited him to call at his house.

The gentleman was Mr. Davies Gilbert, later President of the Royal Society. So convinced was Gilbert of Humphry Davy's

SIR HUMPHRY DAVY

abilities that he allowed him the run of his library and became his lifelong friend.

Gilbert, who had many influential friends, introduced Humphry to Dr. Beddoes, a physician who had set up at Bristol a Pneumatic Institute for the investigation of the medicinal properties of certain gases, and needed an assistant to look after his laboratory.

Told of Davy's work on heat and light, Dr. Beddoes asked to meet Humphry, and finally, satisfied with his capabilities, offered him the vacant post at the Institute.

Beddoes' offer was accepted and at the laboratory Davy was able to make use of good apparatus and to mix with educated

and scientifically-minded men. One of the first of his discoveries there was that pure nitrous oxide is respirable. After breathing in sixteen quarts of it for about seven minutes Davy was absolutely intoxicated, but this effect did little to quench his ardour for experimentation.

It was the publication of his *Chemical and Philosophical Researches* that brought Davy's name to the notice of Count Rumford, who in 1799 established the Royal Institution in London. The first lecturer to the newly founded Institution, Dr. Garnett, resigned in 1801 and Davy was approached and asked if he would accept the post. In 1802 he was appointed assistant lecturer in chemistry, director of the chemical laboratory and assistant director of the Institution's Journals, at a salary of £100 a year "including lodging, coal and candles".

The following year Davy was made a member of the Royal Society and four years later became the Society's secretary.

His feet were now firmly on the ladder of fame. In spite of his rugged appearance and lack of polish Davy's success as a lecturer was instant and undeniable. He had the happy knack of catching the attention of his audience and, above all, of holding it. He came to London at a time when experimental science was gaining popularity and the demonstrations he made during his lectures were ingeniously contrived. It was not long before they were the most popular in London. Fashionable women flocked to hear him and the young lecturer was sought after by London society.

It was at this time that Davy first met a young man by the name of Michael Faraday who came to him for advice and was later admitted to the laboratory. In this way the first opportunity was given to an untried scientist who lived to become world famous.

At the Royal Institution Davy's work on original research prospered. He had the use of one battery of 400 five-inch plates and another of forty plates one foot in diameter. In his first Bakerian lecture to the Royal Society in 1806 he demonstrated that electro-chemical phenomena were only to be explained by one general law, and he illustrated his theory of voltaic action by numerous experiments. This paper gained for him the medal of the French Institute offered each year by Napoleon for the best work on galvanism.

The second Bakerian lecture, given in 1807, disclosed his discovery of the production of potassium and sodium by electrical decomposition of the alkalis and in 1808 he announced the discovery of magnesium and strontium. In fact, the most valuable of Davy's scientific works were given to the Royal

Society, and in most of these some new important discovery or hitherto unrealised principle was revealed.

At the height of his fame, in 1812, Davy was knighted by the Prince Regent, and that same year he courted and married a rich and handsome young widow, Mrs. Appreece, who had gathered round her in Scotland a number of literary and social figures in Edinburgh society.

The marriage was happy up to a point. But the young wife had little understanding of the genius and character of her uncouth scientist husband, and towards the end of their married life Davy found little interest or solace in her company.

In 1813, in spite of the war, Napoleon permitted Davy, his wife and his assistant, Michael Faraday, to visit France, where he met many leading French scientists. In Florence, he was able to effect the decomposition of a diamond in oxygen, by the help of the great "lens" in the cabinet of natural history, and he then decided that beyond "containing a little hydrogen" the stone consisted of pure carbon.

It was after his return to England in 1815 that Davy completed his invention of the Davy lamp. This consisted of a small cylindrical oil lamp covered with a cylinder of wire gauze about six inches long by one and one half inches diameter, and with a flat gauze top. The upper part of the gauze was doubled to prevent it from being worn by the products of combustion. The gauze was mounted in an upright frame, screwed into a brass ring at each end, the upper ring had a handle and the lower end screwed to a collar on the oil vessel at the bottom of the lamp. In this way, encircled with a case of metal gauze, the flame, or gases, could not pass out at a temperature high enough to fire an explosive mixture in the air.

For this invention Newcastle coalowners presented Davy with a piece of presentation plate. In his will this was left to his brother, Dr. John Davy, with a request that if he had no heirs it should be melted down, sold, and the money directed to found a medal to be offered annually for the most important discovery in chemistry anywhere in Europe or Anglo-America. On the death of Dr. Davy, who had no heirs, the plate was sold, realising the sum of £736 and the interest on this money is now expended yearly on a medal.

In 1820 Davy was elected President of the Royal Society on the death of Sir Joseph Banks. Unfortunately, at this time his health began to decline, and he was unable to enjoy his favourite pastimes of fishing and shooting. He suffered an apoplectic fit in 1827 and was forced to leave England for Salzburg. The year after, while living in Rome, Davy had an

attack of paralysis. His wife and brother hurried to his side and he was moved to Geneva, where he died on 28th May, 1829. He was buried in a cemetery outside the city.

During his lifetime Davy received the highest honours. He was created a baronet in 1816 and not only in his own country, but abroad, his name was revered both for his work and for the integrity of his character.

GEORGE STEPHENSON

1781–1848

BETWEEN the years 1791 and 1798 there might be seen working in the colliery yard of the Wylam mine, some eight miles from Newcastle, a smutty-faced boy who drove the mine horse and did any odd jobs that happened to come his way.

Born in the shadow of the mine which dominated the life of the district, the child had toiled almost as soon as he could walk, first tending the horses, later shovelling coal for his fireman father. A poor, unromantic life, to be lived out by an uncouth, unlettered miner, so it seemed. But fate ordained otherwise.

Young George Stephenson never expected to be anything but a miner, but that did not deter him from making good use of the limited facilities around him. Like the Cornish boy, Richard Trevithick, he was fascinated by machinery and never lost an opportunity of watching the mine engineers at their work. It was not long before he knew how to work the pumps and when he was seventeen, after years of working for a meagre shilling a day, he was put to pump minding.

Seeing a book about Boulton and Watt's pumps Stephenson determined to learn to read. Hard work by day, harder brain work at night, that was his life until he had mastered the arts of reading, writing and simple mathematics at a night school.

With Stephenson's love of engines went a natural ability for mechanics. He was a craftsman with an infinite capacity for taking pains and became so well known in the locality as a skilled watch and clock repairer that people would visit him from far and near to have their time-pieces put in order.

When he was twenty Stephenson left his parents' home and went to lodge on a farm at Black Callerton, where he fell in love with Frances Henderson, a young maidservant whom he married the following year.

In 1803 his son Robert was born and, shortly after, the family moved to Killingworth. These were troublous years for Stephenson, for his wife died leaving him with a young baby and he had also to provide for his parents, then too old to work. Added to these worries, he was drawn for the Militia and had to pay out a sum of money to provide a substitute.

There was nothing to be done but to try to work even harder. Luckily, Stephenson was known as a skilful workman, and in

1808 while under contract to work the Killingworth pit engines his ability was recognised and he was given the post of enginewright to the colliery at a salary of one hundred pounds a year.

It was while working at Killingworth that Stephenson began his experiments on a form of safety lamp for miners.

He saw for himself the terrible accidents due to the explosions of fire damp, and his friends often asked him: "George, you're

GEORGE STEPHENSON

a clever inventive sort of chap, can't you do something to prevent this happening?"

Many designs were tried and discarded, but at length he devised a lamp, using glass and wire to prevent the flame contacting the fire-damp. It was tested in the mine and proved successful. Stephenson was acclaimed by the Killingworth miners as a genius. Strangely enough it was at this very time that Sir Humphry Davy, the scientist, produced his miner's lamp. This received a more universal acceptance than did Stephenson's, owing to the fame of its inventor. Stephenson's associates, however, collected the sum of one thousand guineas which they presented to him in a silver goblet as a token of their appreciation of his work.

At this time Stephenson had turned his thoughts to steam locomotion. During the 16th, 17th and 18th centuries it was

the custom of collieries to haul their coal to the nearest port by horse-drawn wagons, a back-breaking job for the unfortunate animals. Haulage roads consisted at first of two lines of wooden "rails" on which the wagon wheels ran. In the 18th century iron plates were laid over the wood, later to be succeeded by cast-iron rails with an inside flange to prevent wheel slip. Already Murdoch had constructed a working model of a steam carriage and Trevithick had built an engine which had run on Cornish roads.

Stephenson had long been considering this question of coal haulage by horses and was sure in his own mind that besides being a slow, uneconomic proposition it was a matter that might be solved if steam engines could be designed, not to run on ordinary roads, but on specially constructed railroads that would avoid too many changes of gradient.

His ideas bore fruit and were demonstrated in an engine of his own design, the *Blucher*, which was so successful that it was used for carrying coal on a nine-mile run from Killingworth to the sea.

Under Stephenson's direction a railroad was laid down, but as this was used only by the mine owners and not for passenger work it did not attract attention from the outside world and for eleven years the engine continued to haul coal from mine to sea.

Then a new idea was born. A project was put forward to connect the towns of Stockton and Darlington by a passenger carrying railroad and a Company was formed to carry out the scheme.

Stephenson was asked if he would survey the suggested route and offered the post of chief engineer to the Company with a salary of three hundred pounds a year.

The scheme was approved by Act of Parliament in 1822. At first the railroad was used for horse-drawn carriages and vehicles as well as trains drawn by locomotives, and was open to any who could pay the required dues. Later, however, the Company restricted its use to their own rolling-stock and on 27th September, 1825, George Stephenson had the honour of driving the first regular passenger train in the world from Stockton to Darlington on his own engine the *Active*.

The thirty-eight-mile long track was single with passing places every quarter mile, and the train ran at twelve to sixteen miles an hour.

Some time before the Stockton and Darlington line was opened Stephenson had set up his own engine works at Newcastle and while the new railroad was still under construction

he had already been approached by another newly organised Company to take an important part in a proposed line to run from Liverpool to Manchester.

This scheme met with long and determined opposition from land-owners and others who felt so strongly on the question that its promoters were even subjected to personal violence.

The first Bill to approve construction was rejected by Parliament, but when a second Bill was introduced in 1826 it was successful and work was immediately put in hand with Stephenson as chief engineer.

There were many difficult problems to be solved before the line was finally completed. A treacherous ten-mile square bog, the Chat Moss, had to be crossed, embankments and cuttings to be overcome. Stephenson laid his track across the Moss by distributing the load over a wide surface of the bog and, as it were, floating his line.

Then came the question of the type of engine to use. The Directors thought that stationary engines at fixed points would be most satisfactory; Stephenson was positive that locomotives were the solution.

Finally, the Company decided to offer a five hundred pound prize to the designer of the best engine for their purpose, the conditions being a mean speed of ten miles per hour with a steam pressure of not more than fifty pounds per square inch.

Ten competitors entered. Five withdrew before the day of the trial leaving five engines to compete: *Cycloped*, *Novelty*, *Perseverance*, *Sans Pareil* and *Rocket*. The last named was Stephenson's design.

Scene of the tests was Rainhill, near Liverpool, on a two-mile level piece of land. Each engine had to run at least seventy miles a day backwards and forwards at the agreed mean speed of ten miles per hour.

Rocket, the only engine, by the way, to be ready to time, ran twelve miles in fifty-three minutes and was eventually awarded the prize after seven days tests. It drew a load of three times its own weight at a cost per mile for fuel of about threepence.

The principal features of Stephenson's engine were an improved steam blast for increasing coal combustion, a boiler in which a large heating surface was given by the use of small tubes through which passed hot gases to cylinders set at a slope instead of vertically. To these was also added a "link" motion contrivance enabling easy reversal of the engine and variation of the amount of compression.

On 15th September, 1830, after the expenditure of £820,000 the new railway was opened by the Duke of Wellington in the

presence of a crowd of nobility, including two ambassadors and many Members of Parliament.

Eight locomotives and their attendant carriages performed to perfection, and in spite of an unfortunate accident to an M.P., Mr. William Huskisson, who fell across a portion of the line and was run over by one of the engines, the opening of the Manchester-Liverpool line marked the beginning of a new era in passenger transport.

All the great railway systems of England came into existence within ten years of that day. Within four years the first sod was cut at Chalk Farm, London, for the laying of the London to Birmingham line. In 1835 there was a boom in railways and in three years 272 railway acts were passed and companies formed with a total capital of 180 million pounds.

Stephenson, who had married for the second time in 1820 a farmer's daughter of Black Callerton, on completion of the Liverpool Manchester railway went to live at Alton Grange, Ashby de la Zouch, where he opened large coal pits in the neighbourhood and interested himself in their development.

It is true to say that from the beginning of the first railway and the success of his engines Stephenson was intimately connected with every railway of note in the country. He held the posts of chief engineer to the Grand Junction line, to the Manchester to Leeds, Birmingham to Derby, Normanton to York and many other lines and there were few railway schemes in which he was not a leading figure.

While the Midland line was being built Stephenson went to live at Tapton House, Chesterfield. There he devoted himself to horticulture and carried out numerous experiments with manures.

In 1848, his second wife having died in 1845, he married for the third time, a Miss Gregory. But after a short time he was taken ill with an intermittent fever and died at Tapton House on 12th August of the same year.

George Stephenson had lived from first to last a life of hardship and hard work. In his early years extreme poverty had been his lot and he was a man of forty-four before his genius began to be recognised.

Physically, he was immensely strong, with great powers of endurance. As a young man he had been a first-class wrestler and he was proud of his strength.

Stephenson was buried at Trinity Church, Chesterfield. His only son, Robert, inherited much of his father's engineering ability and was for many years a co-worker in many of his railway schemes.

MICHAEL FARADAY

1791–1867

SCIENCE interests the average man in its practical applications rather than in academic discovery. He shows little enthusiasm for the most painstaking research if it leads to no practical results.

It could never be said of Michael Faraday, British chemist and physicist, that his time was spent in useless investigation, for it is to his genius that we owe the development of the dynamo, the electric motor and the telephone. From his experiments grew much of the knowledge of the electrical nature of chemical action which led eventually to the industry of electro-plating.

Faraday came from no aristocratic line. He had little schooling and no college career. His father was a poor struggling blacksmith who moved from Yorkshire to a London slum with his family of four, there to ply an ill-paid trade.

As a boy, Michael Faraday seldom had enough to eat, and when he was thirteen he was sent to work to help eke out the family exchequer.

But here fate was kind. He might well have been apprenticed to a butcher, but luckily he found work with a kindly bookseller and bookbinder called Riebau who kept a shop in a mews off Manchester Square, in the West End of London.

Although his job was to run errands for his master, there was always some time in the day when the boy could dip into one or other of the books in the shop. And this was his greatest desire.

A year passed, during which time Michael Faraday gained an exemplary character. Then his master set him to learn bookbinding. His tasks were always well done and he was happy, for had he not more opportunity to read those enthralling volumes, or at least some part of them, so that he could fill his keen brain with what scraps of scientific knowledge he could find. It was always the science books in which he most delighted.

One day a good-natured customer, a member of the Royal Institution, gave Faraday tickets to attend four lectures by the renowned Sir Humphry Davy. That was a red-letter day for the boy. Equipped with note-book and pencils he went to the

lectures. Afterwards, late into the night he wrote out his notes, adding his own diagrams and comments. Then, fired with determination to better his position, he sent his papers to Davy with a note begging for his comments.

Late one evening, shortly after he had despatched his packet, a carriage drew up at his lodging and a messenger alighted with a letter. Faraday opened it with trembling fingers. Davy would see him.

MICHAEL FARADAY

Next day when Sir Humphry Davy entered his laboratory at the Royal Institution he found awaiting him a well set-up young fellow with curly brown hair and animated countenance, intelligence shining in his bright eyes.

Nervous and excited as he was Michael Faraday so impressed Sir Humphry with his quick understanding and enthusiasm that he was offered the post of laboratory assistant at the wage of twenty-five shillings a week.

From that day Faraday never looked back. With Davy he travelled the capitals of Europe where he met and talked with most of the leading scientists and men of letters.

What an experience that was! It opened up an entirely new life. On their return to London Faraday threw himself heart and soul into his work and in 1816, with some diffidence, sub-

mitted his first scientific article for publication. It was on the subject of *Lime* and was well received.

Such was Faraday's genius that in spite of his lack of early training he had the gift of being able to pick from a mass of accumulated facts those which would be useful for whatever work he happened to have in hand.

Ten years after he had entered Davy's service, in 1823, Faraday was made a Fellow of the Royal Society. Later, on Davy's retirement, he took his master's place as Director of the Royal Institution's laboratory.

Although a highly successful chemist, indeed, nearly all his early work was connected with chemistry, Faraday's heart was in original research. A Danish scientist, Oersted, had established that there was a relationship between electricity and magnetism, and Faraday became obsessed by his desire to discover how this could be explained.

It might be said that lines of magnetic force took possession of his mind. When lecturing he would hold up a magnet before his students and tapping it with his hand would say: "Not only is force here, but it is also here, and here, and here," passing his hand through the air surrounding the magnet.

In his fertile brain arose the question "if an electric current causes magnetic effects why should not magnets give rise to currents? Why should not a current of electricity in one wire induce current in an adjacent wire?"

Experiment after experiment was carried out. Some were unsuccessful, but at last by producing movement between a wire and a magnet Faraday discovered the basic principle by which electric motors operate to-day.

But he was not content. "I believe," he said, "that one electric current can lead to the making of another in a separate electrical circuit. By every principle I know, it should induce another current."

He was right. After more hard work he was able to develop the principle on which all transformers and electrical generators are based.

The results of his discoveries are manifold although at the time their true worth was not always appreciated. It was Faraday who replied to an enquirer who wanted to know what use there was in the brilliant electrical discovery he had recently made, "Can you tell me what use is a new-born baby?"

His "baby" grew to lusty manhood and from it came our large power stations, electric lighting, heating, wireless and much of our modern industrial existence.

Faraday's life was, as he wished it to be, one of unrelenting hard work. His persistence in perusing any particular piece of research to a conclusion was phenomenal, he had the infinite capacity of genius for taking pains.. At one time he suffered a three years spell of bad health when he was compelled to abandon his work and live abroad, but, that period apart, he had little time for relaxation.

He was a man of very deep religious convictions, and like his parents before him belonged to "a very small and despised sect of Christians, known, if known at all, as Sandemanians". This is how he described them.

All who knew Michael Faraday admired him, not only for his work, but for his sympathetic and generous nature. He was gentle, kindly and understanding. In appearance he was extremely handsome as a young man and kept his good looks to the end of his life. He was one of the really great Englishmen who found fame in their own lifetime. Faraday was never a rich man, he made little or no provision for his old age, but towards the end of his life he was persuaded to accept a small annuity of three hundred pounds a year and a house on the green at Hampton Court under special direction of Queen Victoria.

It was there that he passed peacefully away one hot August day in 1867, seated in his chair, as if at work, his calm, handsome face turned towards the sun.

SIR CHARLES LYELL

1797–1875

There was published in London, in the year 1838, the first volume of a scientific work written by a British investigator which was to run through twelve editions and become the accepted basis of geology.

The author was Charles Lyell; the title of the book, *Principles of Geology: being An Attempt to Explain the Former Changes of the Earth's Surface by Reference to Causes now in Action.* It was this work which gave the keynote to the writer's life.

Lyell was the eldest son of Charles Lyell of Kinnordy, Forfarshire, and was born on 14th November, 1797, in the family home on the estate.

From his father Charles inherited a love of literature and natural history, and when the Lyells moved to a small estate near Lymington, he was able to indulge to the full the joys of riding and roaming in the New Forest.

School days were spent at Ringwood, Salisbury and Midhurst. In 1816 Charles entered Exeter College, Oxford, and it was there that he fell under the spell of Dr. Buckland, lecturer in geology, with whom he became fast friends, and who encouraged Lyell to devote much of his time to geological study.

Charles was intended for the legal profession, and after taking his degree he joined Lincoln's Inn to study for the bar.

On coming to London he joined the Geological and Linnean Societies, for although prepared to practice his chosen profession there is no doubt that his heart was really in the scientific studies to which he returned whenever possible.

Prior to leaving Oxford Lyell travelled on the Continent with Dr. Buckland, and when a chronic weakness of the eyes forced him to take a rest from his legal work he took the opportunity of again visiting France and Italy.

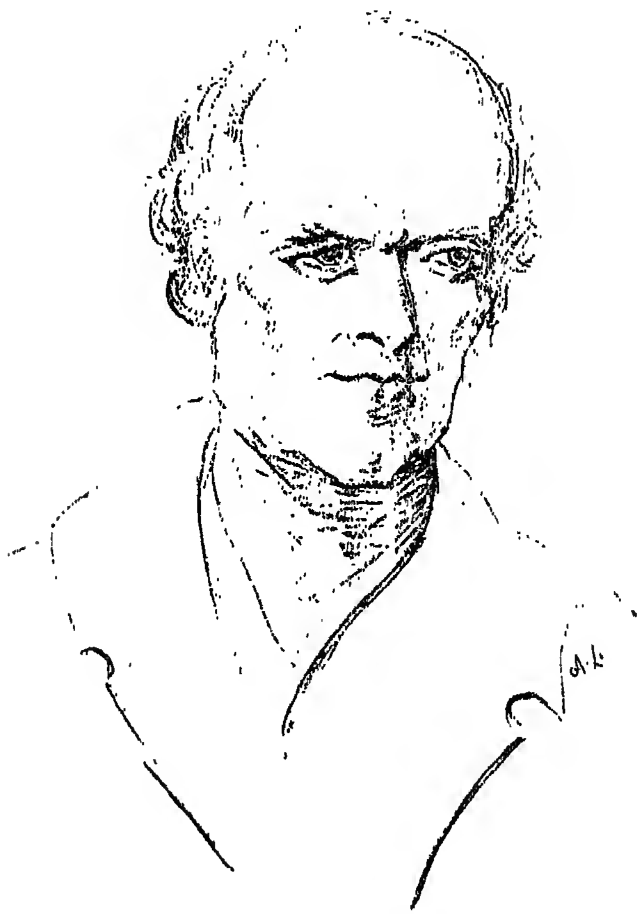
In 1826 Lyell was elected a Fellow of the Royal Society from which, in later years, he was to receive the Royal and Copley medals. By this time he had made many scientific friends, men of standing both in England and on the Continent, and his geological work was held in high esteem.

Law, with Charles Lyell, never had any chance against science. His bad eyesight, and above all his passionate wish to concentrate his activities on geology, at length led to his

abandoning all pretence at legal work and going again to the Continent to carry out more observations.

Already he had begun to plan his great work. This, he realised, meant extensive travel, and in pursuance of his object Lyell went to the United States and Canada.

Properly to assess the value of his investigations it is necessary



SIR CHARLES LYELL

to know something of the background of the scientific field in which he worked.

Nearly half a century before Lyell's *Principles* appeared Hutton, another British scientist, had published his *Theory of the Age of the Earth* which explained the occurrence of valleys,

mountains, and other features of the earth as due to slow, age-long processes of which man could see neither the beginning nor the end.

Hutton directly opposed those thinkers of his day, led by the German, Werner and his followers, who claimed that earth's history had been a series of peaceful periods interrupted by sudden catastrophic upheavals during which whole species were swept away in one fell swoop, this leading, according to the "catastrophics", to the creation of new species.

Theologians encouraged this view and preached that the last of these catastrophes was the Flood, and although there were many who may have thought that these doctrines were hardly credible, there were few who cared to advance any such "heresy".

When Hutton's book appeared few read it, and those who did were either unable to take in its real meaning, or too afraid to support it. Be that as it may, it was not until Lyell published his *Principles* which incorporated a re-statement of Hutton's views, that the "catastrophists" were proved to be false prophets.

Unlike Werner, who travelled little, Lyell studied his subject firsthand. He always claimed that "we must preach up travelling as the first, second and third requisite for a modern geologist", and to this belief he held throughout his life.

In the year 1830 the house of John Murray published the now famous *Principles*, which had an immediate and successful sale. The first chapters gave the death-blow to the "catastrophe" supporters by showing how the face of the earth is being *now* changed by the action of rivers, tides and streams. Beyond question, Lyell exposed the fallacies of the catastrophe theory by proving how hard surfaces of rock and soil are weathered, worn down by rain, frost and wear. How running water of rivers and streams sweeps down carrying with it the sediment which is deposited on the ocean bed, and in slow, but certain processes of time cuts gorges and chasms.

The book was violently attacked. Critics sneered that the work was only a re-statement of Hutton's theories; that the principles were false. All the old jargon of men who were loath to accept any new ideas or facts.

But Lyell was quite unmoved. Most of the scientific world rallied to his support. Before his death he was to see his *Principles* run through eleven editions, each of which was added to by new material so as to make up a complete account of geological advances for the period under review. He was actually revising the twelfth edition shortly before he died.

In 1838 appeared Lyell's second work *Elements of Geology*, and in 1863 his third work *The Antiquity of Man* was published. He was knighted by Queen Victoria in 1848 and made a baronet in 1864. During these later years a warm friendship was set up between Lyell and the Prince Consort, which remained unbroken.

Lyell was a married man. His wife, formerly Miss Mary Horner, was a clever woman, able to assist him in much of his work, and in their London home they gathered round them a small scientific and literary circle.

Beloved of his friends, a man of warm and kindly nature, Lyell was highly esteemed by the scientists of his time. Charles Darwin was a close friend, and it was Lyell whose advice was sought by Darwin when he first had news of the work carried out by Wallace on lines similar to his own.

Lyell was one of the first to acknowledge the worth of Darwin's work on the publication of the famous *Origin of Species*, and in one of his own books he pays homage to the great naturalist.

The words of Darwin, written after the death of Lyell in 1875, are a fitting epitaph to a fellow scientist: "The science of geology is enormously indebted to Lyell, more so, as I believe, than to any other man who ever lived."

WILLIAM HENRY FOX TALBOT

1800–1877

To-day, thanks to the work of science in making photographic material foolproof, it is true to say that almost anyone who can press a button can take a photograph.

Yet, just over one hundred years ago photography was unknown, and the artist in colour or black and white was the only visual interpreter of scenery and objects. All the more remarkable therefore is the progress made since the days when the British scientist, William Fox Talbot, first found a way to make, what were then called "sun pictures", permanent.

Talbot, who was the only child of William Davenport Talbot of Lacock in the county of Wiltshire, was born on the 11th February, 1800.

His mother was daughter of the second Earl of Ilchester and William was brought up in wealthy county society. He received an expensive education at Harrow School and Trinity College, Cambridge, where he was twelfth wrangler, and second chancellor's medallist in 1821, and took his B.A. and M.A. degrees.

William Talbot was a fine mathematician, and delighted in any form of mental exercise. For years he studied and wrote articles on scientific matters, astronomy, physics, chemistry, archæology and mathematics, and was proficient in all.

The year after he left college he began to experiment in the chemical action of light and sent the results of some of his investigations to the Edinburgh *Journal of Science*.

While on holiday in Italy in 1833 he was sketching by the shores of Lake Como and, to help him in his work, used a device known as a camera lucida, which enabled an artist to look through a four-sided prism and make a general drawing of the scene before him.

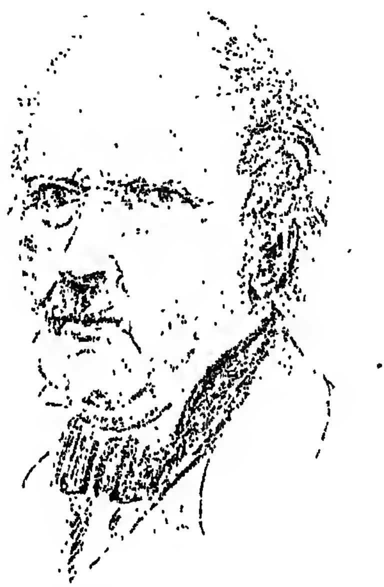
Talbot found this method far from satisfactory, and to his critical mind little of the beauty of the scenery was transferred to the paper. Then he tried, with the help of a camera obscura which allowed the view to be thrown on to ground glass and then copied.

Surely, thought Talbot, there should be some way by which a picture presented through the camera obscura could be "caught", as it were, and made permanent.

His mind grappled with this problem, but at the time he

could see no way of solving it. However, it was not his nature to give up, and from that day he determined to work out some method of "catching" and keeping pictures.

He found that Thomas Wedgwood, son of the famous pottery maker, Josiah Wedgwood, had actually produced sun pictures on sensitised paper and Talbot began to follow up these experiments.



WILLIAM HENRY FOX TALBOT

He would place different objects on sensitised paper, allow light to fall upon them and thus render their outlines in white on a black background. But the marks faded away quickly, and the problem still remained, how to fix them permanently.

Then quite accidentally, Talbot hit upon a compound with a greater sensitiveness to light. He was using ordinary common salt in solution on silver nitrate when he noticed that certain parts of the paper made better prints than others, and he was soon able to produce clearer prints than ever before. There was, of course, no question of a camera of any kind in this work. Talbot made his pictures merely by laying objects direct on to his sensitised paper and then printing them off.

It is noticeable that often in scientific research workers in different countries arrive at similar results without apparent co-operation. This was the case in the matter of photography,

for at the same time as Talbot made his experiments in England a French worker, Louis Daguerre, was doing much the same work in France.

There seems little doubt that Daguerre got wind of Talbot's work first, and in consequence communicated his own results to the Academy of Science in Paris on 7th January, 1839.

Talbot heard of this almost immediately, and following a brief description of his own work given to the Royal Institution by Faraday on 25th January, he sent to the Royal Society on 31st January an account of his research entitled *Some Account of the Art of Photogenic Drawing, or the Process by which Natural Objects may be made to delineate themselves without the aid of the Artist's Pencil.*

The following year Talbot's work was crowned with success for he discovered a way of making a permanent sun picture. By using paper sensitised by iodide of silver and nitrate of silver he obtained an invisible image which could be rendered visible by treatment with a gallic acid solution and then fixed by sodium hyposulphite.

So sensitive was this paper that a picture was obtained within an exposure of only half a minute. Talbot was the first man to print pictures from negatives in this way and make many reproductions from a single exposure. The name given to the process was "Calotype" from the Greek words *kalos*, beautiful, and *typos*, example or picture. Later it came to be called the Talbotype.

Other discoveries followed the Calotype. In 1851 Talbot found a way of taking instantaneous photographs, in 1852 he invented a method of photographic engraving, and the next year he obtained a gloss on photographic prints by means of albumen. All these methods he patented and at the request of the Royal Society and the Royal Academy he threw open his discoveries for sale to the public with the exception of portrait taking.

The rivalry between Talbot and Daguerre lasted until the Talbotype eventually drove the Daguerreotype out of the field and the French awarded Talbot the gold medal at the Paris Exhibition in 1867.

The name made by Talbot in the field of photography tended to overshadow his work in other branches of science. He did, however, make many valuable contributions to literature and archæology and was one of the first men to decipher cuneiform writings brought to England from the ruins of Nineveh.

He was a member of the Royal Astronomical Society, a

Member of the Royal Society and sat for the Reformed Parliament for Chippenham from 1833–1834.

His mathematical work was brilliant, and of his writings the *Pencil of Nature* published in six parts in 1844 was the first book ever illustrated by photographs made without the aid of a pencil. It is now extremely rare.

William Fox Talbot died on 17th September, 1877, at Lacock Abbey. His portrait may be seen in London, in the South Kensington Museum, where it is included in the collection of "Fathers of Photography".

SIR CHARLES WHEATSTONE

1802–1875

The name of Charles Wheatstone should never be forgotten, for his inventions, probably more than those of any other man, helped to link up the countries of the world by making possible speedy communication between individuals and nations.

By his work on the telegraph and many forms of telegraphic communication he brought about the world-wide economic developments of the latter half of the 19th century.

Wheatstone, the inventor and creator of delicate and beautiful mechanical devices, was a man of foresight, keen reasoning powers, unbounded patience in research, and wide knowledge. Wheatstone the ordinary man was shy, diffident and sensitive, terrified of society, a poor speaker and an extremely bad presenter of his own remarkable work. In fact, most of the papers in which his discoveries were announced were communicated to the Royal Society by Michael Faraday, who was never too busy to give a helping hand to any young scientist.

Charles Wheatstone was son of a Gloucester tradesman, a seller of musical instruments. The boy was educated at private schools. He was unusually precocious as a small child and could read fluently at the age of four. As he grew older his passion was for making models, copying some of those in his father's shop or inventing others of his own.

It seemed that he had music in his blood for before he was twelve he was making musical instruments and experimenting with sound and light.

At sixteen Charles was sent to London to live with an uncle, who was an instrument-maker in the Strand. As an apprentice the boy was hardly a success, but neither his father nor uncle were unduly perturbed and Charles was encouraged to the top of his bent to indulge his love for reading and experimentation.

One of his earliest instruments was the acoucryptophone or "magic lyre". Exquisitely made, this was an elegant, lyre-shaped box which could be suspended by a metallic wire from a piano in the room above. On playing the piano the performer thereby caused vibrations which were transmitted silently and became audible in the hanging lyre, which thus appeared to play of itself.

On his uncle's death in 1823 Charles and his brother took

over the Strand business. Charles was no business man and it suited him to leave practically the whole of the work in his brother's hands while he gave his own time to scientific research, mainly in connection with sound and light.

It was in the same year that his paper on *New Experiments on Sound* appeared in Thomson's *Annals of Philosophy* and received so enthusiastic a reception that they were translated and published in many continental journals.

SIR CHARLES WHEATSTONE

By 1834 Wheatstone's reputation for original research was acknowledged in scientific circles and he was appointed Professor of experimental physics at Kings College, London.

It was about this time that Wheatstone determined, by means of a rotating mirror, the speed of electrical discharge in conductors, an invention that led to important developments. Noticing the high velocity of electric currents the possibility of using them for sending messages first occurred to him.

To further the success of his inventions Wheatstone entered into a business partnership with William Fothergill Cooke, an arrangement that proved extremely advantageous to both

parties. The merit of being the first to make the automatic telegraph available for the transmission of messages is due to these two men. Among the many inventions patented by them were the letter-showing dial telegraph, the type-printing telegraph, magneto electric dial telegraph, and automatic transmitting and receiving instruments by which messages could be sent and received with great rapidity, up to the rate of 500 words a minute.

When experimenting on transmission rates Wheatstone ran half a mile of insulated copper wire in the vaults under Kings College. This circuit was interrupted by three pairs of brass knobs. A Leyden jar was then discharged through the wire and the space of time between the occurrence of sparks at the ends and the occurrence of a spark at the middle was carefully noted, as well as the displacement of the image of the middle spark in a mirror revolving at a known speed.

Wheatstone devoted many years of research to submarine telegraphy. He carried out experiments in Swansea Bay and from his early work with submarine cables foresaw the possibility of this means of communication.

Among his many talents Wheatstone possessed an extraordinary facility for deciphering hieroglyphics and ciphers. He liked nothing better than to be confronted with an MS. which no one had ever been able to read, and there are many in the British Museum which were apparently indecipherable until Wheatstone set to work on them. He invented an amazing cryptographic machine which changed the cipher automatically and printed a message which was absolutely unintelligible until translated by a duplicate machine.

Many contributions were made by Wheatstone to the science of light and optics. The conception of the stereoscope, now well known, is entirely due to him. The Polar Clock is another example of his ingenuity. It was known that the light plane, or polarisation of light from the sky is always ninety degrees from the sun. Wheatstone devised a clock by which it was possible to tell the hour of the day by the light in the sky, even though the sun might be invisible. He also invented a system of electro-magnetic clocks for indicating time at different places united on a circuit.

Another of his inventions was the Kaleidophone, which consisted of a steel wire or rectangular cross-section connected to a heavy base and bearing a silver bead at the top. The vibrations of the bead described curves illustrating the combination of harmonic motions of different bodies.

In his lifetime many honours were conferred on Charles

Wheatstone. He was a Fellow of the Royal Society, and received distinctions and diplomas from numerous foreign scientific societies and governments. In 1868 a knighthood was bestowed upon him on completion of his greatest invention, the automatic telegraph.

Of the papers he wrote on scientific subjects probably the best known are those on Chladni's figures, the transmission of sound in solids and a new musical instrument, the concertina.

Wheatstone died in October 1875 from a chill contracted while on a visit to Paris in connection with his receiving instrument. Of the man himself much remains hidden for he disliked social life and seldom entered society, but his work will be for ever a reminder of the greatness of his scientific attainments.

CHARLES ROBERT DARWIN

1809–1882

When studying the lives of great scientists of the past we cannot fail to notice how broad is the range of their work. Many of the most brilliant advances in research have been made by men who had the genius to perceive the relationship between their own discoveries and those made by others in apparently unrelated fields.

Of the men whose work has influenced the world the name of Charles Robert Darwin stands foremost. In the light of his theory of evolution all branches of science became more closely correlated, and the search for other links in the chain of life intensified.

For many centuries theologians and scientists accepted without question the idea that all living species on this earth were fixed and immutable; each had been separately created by Divine Providence.

In the 18th century there came a change in the trend of scientific thought. Keen thinkers began openly to doubt the truth of this so-called law of immutability, and from their own direct observations of nature grew up the first ideas concerning evolution.

Erasmus Darwin, grandfather of Charles, Thomas Huxley, Charles Lyell the geologist, and Joseph Hooker, the botanist, were English scientists who worked, each in his own way, to find some law that would fit better the facts of the animal and plant creations as they found them.

It was into this world of changing thought that Charles Darwin was born in 1809, son of a popular Shrewsbury physician and one of a family of six.

When a youngster, Charles showed an eagerness to collect and study plants and insects. Like his father and grandfather before him he had the faculty of observation that was to serve him so well.

During school and college days at Edinburgh and Cambridge the boy's keenest wish was to be a naturalist. But although his father acknowledged Charles's enthusiasm for what he called his "hobby", the family considered this to be a blind alley so far as a profession was concerned. It was the elder Darwin's intention that Charles should follow in his own footsteps and make medicine his career.

For medicine, however, Charles showed no inclination. Then it was suggested that he should enter the Church.

This latter idea Charles accepted, more because nothing else presented itself at the time than because he really felt he had a vocation.

CHARLES ROBERT DARWIN

In character Charles Darwin was liberal minded and of exceptional charm. All who met him fell under his spell, and to this personality, was added an honourable and truth-loving nature

At college he showed no trace of the ill-health that was to hinder him so sorely in later life. He was tall and thin, with a ruddy complexion, blue-grey eyes and deep over-hanging brows and high intellectual forehead.

Charles got the great chance of his life in 1832 when he was offered an appointment as naturalist to the government ship H.M.S. *Beagle* which had been equipped to extend the survey of South America and "carry a chain of chronometrical measurements round the world".

Rather grudgingly, Dr. Darwin allowed Charles to accept the post, and on 27th December, 1831, the *Beagle* sailed from England and the investigations began that were destined to bring the work of the youthful Briton before the world.

Throughout five years of strenuous travel, hampered by fierce bouts of seasickness, Charles Darwin searched, observed and painstakingly noted in his journal everything he came across, till his mind seethed with the problems concerning the different species of plants and animals he found.

The more he examined his specimens the more he wondered. Why was there so great a difference between individuals of the same species? Was each individual created separately? Why were no members of the same species exactly similar?

For five years he worked and thought. Then, completely, he abandoned the old worn-out conception of the immutability of species. In his own words, he found that from what he had discovered for himself, "it was evident that such facts as well as many others could only be explained on the supposition that species gradually became modified".

In 1836 the *Beagle* returned to England and Charles Darwin's career as a naturalist was assured.

He set about the preparation of his notes for publication, and on the appearance of his *Journal of Researches into the Natural History and Geology of Countries Visited During the Voyage of H.M.S. Beagle Round the World* he was accepted as an established man of science.

Three years later Charles married his cousin, Emma Wedgwood, and left London to settle in the Kentish village of Down.

In the peaceful seclusion of the English countryside he gave himself up to hard and systematic work. In spite of the ill-health that never left him for the remainder of his life, he carried on with his search to discover the natural causes of the origin of species.

Deeper and deeper he probed into the mystery. Letters reached him from others workers all over the world. He roamed fields and villages talking to farmers and botanists,

collecting more and more information, steadily progressing towards the heart of the problem.

It was borne in upon Darwin that in the bitter fight for survival only the fittest endured. Every plant, insect and animal must adapt itself or die. A species that varied itself to suit its environment was able to continue; modifications were then carried on from one species to another and by slow, sure processes came the evolution of new species. Here, surely, was the key to the riddle!

From his mass of notes work on a new book was begun. In 1859 was published the *Origin of Species*. The whole edition of more than a thousand copies was sold out the first day. Here was a work to shatter the old beliefs of theologians and scientists alike.

A bitter controversy at once broke out. Theologians denounced the author of this "infamous book" and declared his work to be "an utterly rotten fabric of guesses and speculation". Some scientists also held back from giving a verdict, but the majority of his fellows were loud in praise and in spite of a campaign of calumny and opposition from the Churches it was not long before Darwin conquered. The new evolutionary theory spread over the world wherever men met and discussed together, like a rushing, mighty wind, tearing to shreds and tatters old superstitions.

Honours and awards poured in on Charles Darwin from all quarters of the globe. But he was content to live peacefully at Down, working, writing and entertaining his friends.

One of the bitter taunts made by Darwin's critics was to the effect that he was afraid to speculate on the origin of man. To silence this criticism he wrote *The Descent of Man* which, in effect, dispelled the hopes of many that he would be able to prove that Man alone was indeed a fixed species.

Darwin wrote many other books, mainly on the habits of plants and flowers, which remain unequalled to this day.

After years of sickness, he died at Down, the house he loved so well, in 1882, and the nation that had honoured and respected him during his lifetime insisted that he should be buried in Westminster Abbey. There he was laid to rest close to that other great British scientist, Isaac Newton.

The best description of Darwin, perhaps, is given in his own writing. He had "unbounded patience in long reflecting over any subject, industry in observing and collecting facts, and a fair share of invention as well as commonsense".

JAMES PRESCOTT JOULE

1818–1889

"The award of two medals for the same researches is an exceedingly rare proceeding in our Society, and rightly so. The Council have on this occasion desired to mark by it in the most emphatic manner their sense of the special and original character and high desert of Mr. Joule's discovery."

So spoke Sir Edward Sabine in 1860 on presentation by the Royal Society of the Copley Medal to the British scientist James Prescott Joule for his research into the production of heat by friction. Eight years earlier a Royal Medal had been awarded by the Council to him for the same work.

Gratified as Joule must have been by this recognition it is however more than likely that he remembered that it was the Royal Society which had previously refused to publish his first paper. No doubt he also remembered with some degree of humour his own words on that occasion. "I am not surprised," he then remarked: "I quite imagine those gentlemen in London sitting round a table and saying to each other, 'What good can come out of a town (Manchester) where they dine in the middle of the day'."

Joule, like Faraday, was not a university man, and the doors of that august body, the Royal Society, were, at that time, shut to many who through lack of academic degrees, had not the entrée to London scientific circles.

James Prescott Joule came from a family of prosperous brewers of Salford, near Manchester, and was born on Christmas Eve, 1818.

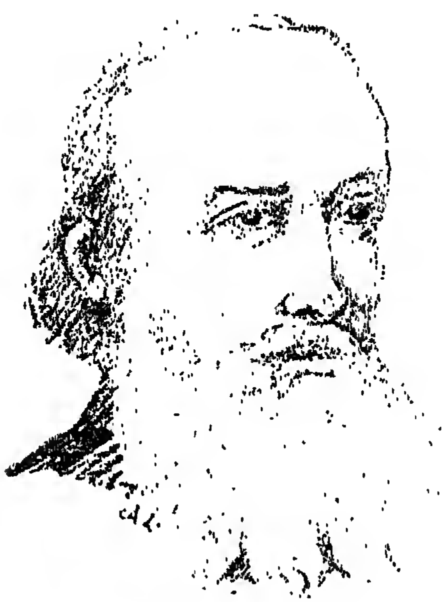
As a lad he was delicate and could not attend school. For years he learned at home, and at seventeen he and his elder brother Benjamin were fortunate enough to be tutored by John Dalton, then President of the Manchester Literary and Philosophical Society.

Under Dalton's tuition they learned algebra, geometry and chemistry, and from his tutor James received the stimulus to undertake scientific research that led him to become one of the foremost physicists of his day.

So great was his enthusiasm for experimenting that he fitted up a rough laboratory at home and every spare moment of his time was spent in investigating problems of magnetism and electricity.

The results of some of his early work may be read in the papers he published. One that appeared in 1840, when he was twenty-two, dealt with what was practically the first attempt to measure electric current in terms of a unit. This was defined by Joule as a current which will decompose nine grains of water if passed for an hour through a water voltameter.

Lecturing in Manchester the following year Joule stated that



JAMES PRESCOTT JOULE

he had discovered experimentally that "an iron bar is increased in length when magnetised". He explained that this had been suggested to him by an "ingenious gentleman of the town".

Dalton was present at this meeting to hear his pupil and moved a vote of thanks to him after the reading of his paper.

Joule's connection with the Society was one of the happiest and lasted throughout his life. In 1844 he became its librarian, honorary secretary in 1846, and President in 1860.

Two great physical laws are linked with Joule's name. The first, which was announced to the scientific world in the Proceedings of the Royal Society in 1860 was contained in his paper on *the Production of Heat by Voltaic Electricity.*

Prior to Joule's work Ohm had found the law, now known as Ohm's law, and Davy had experimented in measuring heat

produced by passing current through wires of different materials. It remained for Joule to define the law that "when a current of voltaic electricity is propagated along a metallic conductor the heat evolved in a given time is proportional to the resistance of the conductor multiplied by the square of the electricity intensity". For the first time also mention was made in Joule's paper of a "standard of resistance".

The second great discovery of Joule's was in connection with the equivalence of energy and heat which was to be more fully developed in later years.

A number of remarkable experiments made by Joule were submitted in a paper on *The Calorific Effects of Magneto Electricity and on the Mechanical Value of Heat*, read before the British Association.

Joule found that mechanical equivalent of heat in four different ways. The first by rotating a small electro-magnet in water between two poles of another magnet. He measured the heat developed in the water and other parts of the machine, the current induced in the coils and the energy required to maintain it.

The second experiment was based on the heating effects observable when water is forced through capillary tubes, and the third included observations of heat produced by mechanical compression of air. Joule's fourth experiment was the well known frictional one of churning water with a paddle-wheel.

It was after reading one of his papers at Oxford in 1847 that Joule first met William Thomson, later Lord Kelvin, an acquaintanceship that ripened into friendship. Shortly after this Joule married, and on his honeymoon in Switzerland again met Thomson, whose encouragement for his work led Joule to repeat some of his experiments in connection with the frictional production of heat. The combined work of Thomson and Joule led to the development of that branch of science we now call thermodynamics.

Up to 1872 Joule was actively at work, and the collection of his papers by the Physical Society of London are proof of the wide scope and originality of his researches. He appreciated the importance of really accurate measurement and one of his chief aims was to obtain exact quantitative data.

The principle established by his work in Britain and that of Robert Mayer on the Continent set up what is known as the Conservation of Energy. Briefly, it states that the sum total of the energy in the world is constant. If energy in one form disappears an equaivalent amount in another form appears elsewhere.

In 1887 Joule was to have presided over the meeting of the British Association at Manchester, but illness prevented his attendance, and he died on 11th October, 1889.

He received many honours for his services to science. A civil pension of two hundred pounds a year was granted him in 1878 and he received the Albert Medal of the Society of Arts in 1880.

JOHN TYNDALL

1820–1893

THE middle years of the 19th century saw scientists and theologians joined in battle, brought into open conflict by the publication of Charles Darwin's *Origin of Species*.

In that historic struggle between superstition and reason the name of John Tyndall is linked with those of Darwin and Huxley. Tyndall believed that science should not be the property of a few men of science, but that it should be widely taught to ordinary people. He was, indeed, the first great scientist who tried to popularise science and render its complexities understandable to the man in the street.

Born on 2nd August, 1820, in Co. Carlow, Ireland, John Tyndall was son of a landowner of small means.

No education was possible for the boy except that of the local National School, but from his father he had inherited more than average intelligence, and by sheer dogged hard work allied to a natural bent for mathematics and drawing, John Tyndall was able at nineteen to obtain a minor post in the Ordnance Survey of Ireland.

Within three years he became so good a draughtsman that he was selected for a post in the English Survey and left Ireland to work as a railway engineer in Lancashire.

It was while on railway work that Tyndall first came across a copy of Carlyle's *Past and Present*. He said himself that from that day when he began to read the great master, he was a changed man. Under Carlyle's spell the young engineer felt his own ideas begin to develop. He felt the pull of a scientific career, and determined, if possible, to work to this end.

In 1848 the chance came of a change, and Tyndall was offered a post as teacher of mathematics and surveying at Greenwood College, in Hampshire. At Greenwood he met another young teacher, Edward, afterwards Sir Edward, Frankland, with whom he struck up a friendship.

Frankland, who lectured in chemistry, was, like Tyndall, anxious to learn more than was possible in his present position. Eventually they decided to give up their work at Greenwood, and without much to help them except their youth and brains the two travelled to Germany and entered the University of Marburg.

Given the opportunity to study, Tyndall, by extraordinary application accomplished a three years course within two years and obtained his Doctorate in Natural Philosophy.

While he was abroad he had been making investigations in magnetism. In 1850 he came over to England, and at a meeting of the British Association in Edinburgh read a paper on his

JOHN TYNDALL

Investigations into the Magneto Optic Properties of Crystals and the relation of Magnetism and Dismagnetism to Molecular Arrangements.

The paper attracted interest in the scientific world, and for the next five years Tyndall carried on with his researches. In 1851 he left Marburg and returned to Greenwood College as lecturer on mathematics and natural philosophy, and in the same year he met Thomas Huxley, with whom he became friendly.

Tyndall established his reputation by a lecture he delivered in 1853 at the Royal Institution, entitled *The Influence of*

material Aggregations upon the Manifestations of Force. Shortly after this he was offered the Chair of Natural Philosophy at the Royal Institution and, upon his acceptance, there began his happy association with Michael Faraday which lasted until the death of the latter.

Between these two brilliant men grew up a relationship like that of father and son. Tyndall's career was now established, and it was at the Royal Institution that most of his best work was done.

Tyndall was keenly interested in the problem of glacial motion. He had been persuaded by Huxley to join him in a trip to Switzerland and the grandeur of the Swiss mountains and scenery so impressed Tyndall that he made it a regular practice to visit them every year during his holidays. Mountaineering appealed to him tremendously, and he became an ardent alpine climber and made the earliest crossing of the Matterhorn.

In 1850 Faraday demonstrated that two pieces of ice with moistened surfaces would, if in contact, adhere, owing to the freezing of the film of water between them, while at a lower temperature than thirty-two degrees and with dry surfaces no adhesion took place.

From these experiments Tyndall was led to try the effects of compression on ice, and found that a quantity of pounded ice could be moulded into a compact homogeneous mass. This property of reuniting by pressure after fracture was called regalation and was applied by him to explain the motion of glaciers.

He maintained that the ice of a glacier is a solid, brittle substance, and its descent down a valley is due to constant fracture, and sliding forward of the mass in which the surfaces of the fracture unite.

Many different theories regarding glacial motion were advanced and many arguments arose, but, in the main, Tyndall's explanation was generally accepted.

His name will always be associated with his work on heat and its relation to gases and vapours. In 1866 he succeeded Faraday as scientific adviser to Trinity House and the Board of Trade, and it was in connection with the Elder Brethren of Trinity House that his investigations on sound were undertaken, with a view to setting up fog signals along the English coast.

Tyndall found that the non-homogenity of the atmosphere affects sound as cloudiness affects light, and he discovered the existence of acoustic clouds, that is to say, large pockets of air so clear as to be nearly opaque to sound.

He advocated a steam siren in the South Foreland experiments and was called upon to report on the gas system introduced in the lighting of modern lighthouses.

As a popular lecturer Tyndall scored many successes. He charmed audiences both by his manner of explaining the most difficult subjects in a simple way and also by the illustrations he used to demonstrate his points. More than any other man of his time did he bring science to the ordinary citizen. After a lecture tour in the United States he gave the whole of the proceeds, nearly seven thousand pounds, for the encouragement of science in that country.

Tyndall wrote and published many scientific papers and books. His *Heat as a Mode of Motion* was the first published book on that subject, and his views on the relationship between theology and science which appeared in 1874 aroused much controversy.

In 1876 Tyndall married a daughter of Lord Claude Hamilton. A few years later he built a house at Hindhead, Surrey, where he settled down on retirement from the Royal Institution in 1885. During much of his life Tyndall suffered from insomnia, and in 1893, following a trip to Switzerland he accidentally took an overdose of chloral and died from its effects on 4th December.

John Tyndall was a man of great and noble character. He had high principles and ideals, but could at the same time be tender and considerate to others of less fine scruples. Injustice of any sort he could not tolerate. An example of this was shown in his defence of Dr. J. R. Mayer, a man who Tyndall knew to be one who had received little or no credit for much excellent work.

SIR FRANCIS GALTON

1822–1911

In 1798 Thomas Robert Malthus proclaimed to the world through his now famous *Essay on Population* the tendency of human beings, when unchecked, to reproduce themselves beyond the available food supply. Population, he claimed, increased in a geometrical ratio while food only increased in an arithmetical ratio.

Born fifty years later, another Briton, Charles Darwin, was struck by a chance phrase when reading Malthus's Essay—"the struggle for existence". He remembered this when searching for a clue to the biological changes in the process of natural selection, and in 1859 published his theory of evolution.

It was from Darwin's *Origin of Species* that his cousin, Francis Galton, was inspired to investigate the factors that lead to the improvement or deterioration of the human race from a biological angle, and to-day the world recognises him as the founder of the science of Eugenics. Meteorologist, psychologist and explorer, Galton was each of these, but it is in the field of eugenics that his lasting fame is found.

Francis Galton was fortunate in being able to pursue his life work free from the spectre of want. Youngest son of a banker, Samuel Tertius Galton, he came of a well-to-do family with many rich and influential friends; on his mother's side he was grandson of the poet scientist Erasmus Darwin.

Educated privately and at King Edward School, Birmingham, it was early decided that Francis should become a doctor and when his school days were ended he studied first at Kings College medical school, and later for a year at Trinity College, Cambridge.

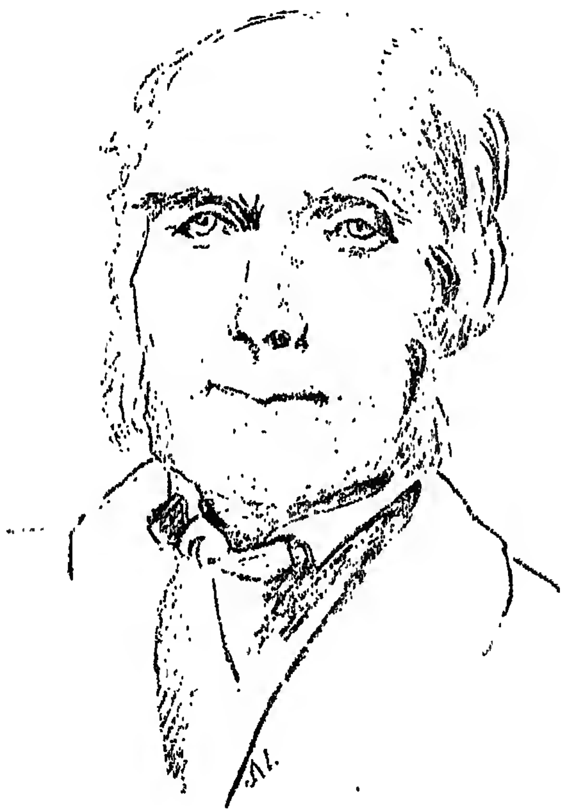
Then came a great change in Francis Galton's life. His father died when Francis was twenty-two and the young student found himself possessed of an adequate private income.

One of his great wishes had always been to travel. Now the chance had come. The medical career was thrown over and Francis joined an expedition that was to travel in the East. Later, at his own expense, he set out to explore Damaraland and the Ovampo country in south-west equatorial Africa.

On his return to England Galton published two books, *An Explorer in Tropical South Africa*, and *The Art of Travel*. His name

as an explorer was mentioned publicly, he began to play an active part on the Council of the Royal Geographical Society and in 1856 was elected a Fellow of the Royal Society.

Unfortunately the hardships suffered by Galton during his travels in Africa so affected his health that he was debarred from ever undertaking strenuous travel again, although he still made extensive trips on the Continent.



SIR FRANCIS GALTON

Scientific research became his life work. The study of meteorology fascinated him. In his work *Meteorographica* he made the first serious attempt to map the weather on any large scale and laid the foundations of the weather forecasting system now operating in the civilised world.

To-day, we are well used to the term "anti-cyclone". It was Galton who first established the existence of these air

currents, as well as introducing the term by which they are now known.

But meteorology was only one and that not the strongest of Francis Galton's scientific interests, and by 1865 he was deeply engrossed in investigating the laws of heredity.

When Darwin's *Origin of Species* first appeared, Galton, in a letter to his cousin frankly acknowledged that "the appearance of the book forms a real crisis in my life. It drove away the constraint of my old superstition as if it had been a nightmare and was the first to give me freedom of thought".

From that time, for over forty years, Galton's life was devoted to the study of heredity. He delved deep into the laws that govern human behaviour. He realised that the laws of selection that led to the breeding of better animal stock are, basically, those which mankind might use to strengthen the race.

To him it was abundantly clear that a good environment was not all that was necessary to improve the race, there must be a change for the better within as well as outside a man. What the world needed was not more children, regardless of the stock from which they came, but better children from the best stocks.

His work revealed to him the way in which the degree of relationship between any pair of attributes for any pair of individuals may be estimated by a numerical factor, as well as the numerical estimate of the average contribution of parents and even more distant ancestors to each person.

After many years of research Galton gave the world the science of Eugenics, defined by him as "the study of agencies under social control which may improve or impair the racial qualities of future generations either physically or mentally".

Eugenics, a word coined by Galton from the Greek word meaning "well-born", has two aims, the prevention of reproduction by individuals of defective types, and the encouragement of reproduction by sound stock.

Galton knew too well that society would need to be re-educated in this new science and that many years must pass before man was impressed by the necessity for improvement of racial qualities. With this object in view he founded the Eugenics Society and in 1904 set up an Eugenics laboratory to work in conjunction with the biometric laboratory of University College, London.

During the present century many organisations all over the world have been founded to promote research in eugenics. On Galton's death in 1911 it was found that he had left funds to establish a Chair of Eugenics at London University with the wish that Dr. Karl Pearson be the first Professor.

Galton made many important studies during his research into the laws of heredity. His collection of finger-prints, started as a possible means of identity, confirmed earlier investigations by Herschel and Faulds and was the basis of methods now in use in the criminal departments of every civilised country.

He demonstrated the significance of colour blindness, and showed how different minds are differently impressed by colour and visual images. He experimented on smell, taste, muscular sense of weight and the strange patterns caused by numbers in the minds of individuals. Amongst his many discoveries was a method of composite photography in which each member of any group makes an equal impression on the resulting picture.

Francis Galton never married. He was, however, a popular figure in society wherever he went, and much sought after for his genial good humour and ready wit.

In his lifetime he received many honours. Two years before he died he was knighted by letters patent. In his campaign for the spread of the knowledge of eugenics he met calumny and opposition, but he was not the man to be daunted in work for what he so earnestly believed was the good of the whole human race. His aim was to teach man to civilise his reproductive instincts. "The world," he wrote, "must learn the science of rearing human thoroughbreds."

LORD KELVIN

1824–1907

In the years 1851, 1853, and 1856, submarine cables were successfully laid between France and England, Holyhead and Howth and across the Gulf of the St. Lawrence. And in 1856 the Atlantic Telegraph Company was formed in England with a capital of £350,000 to promote cable-laying between Ireland and Newfoundland.

On the Board of Directors of this company appeared the name of Professor William Thomson, of 2, The College, Glasgow, nominee of the Scottish shareholders and a scientist whose work on the properties of long cables had already been published under the title of *The Theory of the Electric Telegraph.*

The first attempt to lay a cable across the Atlantic in 1857 was a failure, for it broke at 2,000 fathoms. However, the following year, the company's efforts were crowned with success when, under the supervision of Prof. Thomson as electrician, the operation was carried out and a cable laid between Valentia, Ireland, and Hearts Content, Newfoundland.

Clear messages were exchanged and the cable operated for thirteen months when it was disturbed in deep water and it was not possible to carry out repairs.

For eight years research and preparation went on until in 1866 a new cable was laid and on his return to England from the expedition Prof. Thomson received a knighthood in recognition of his services.

This scientist who played so large a part in the work of the Atlantic Telegraph Company was a man who from his earliest years was endowed with that superlative mixture of sterling character and brilliant intellect.

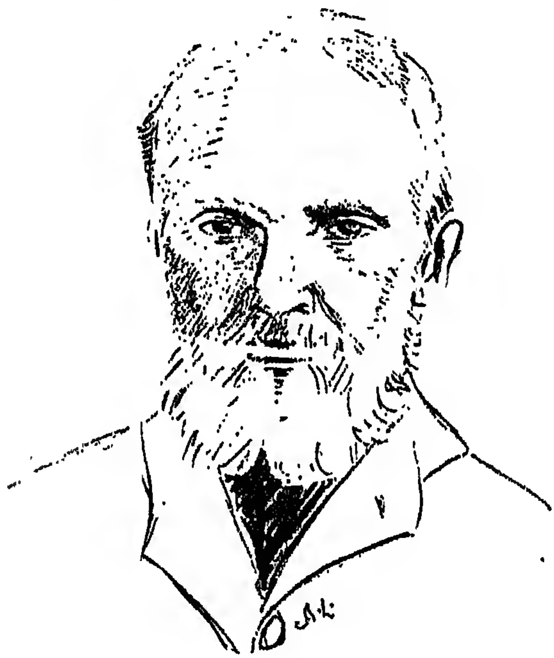
Second son of a professor of mathematics in the Royal Academy of Belfast, William Thomson was born on 25th June, 1824. Neither he nor his brother James attended school. Their father had his own ideas on the subject of education and the boys were taught by him at home.

William soon showed that he had inherited his father's mathematical ability as well as an extraordinary aptitude for absorbing knowledge of all kinds. He matriculated at Glasgow University when he was eleven years old after his father had

moved there from Belfast, and at the age of seventeen won the University medal for an essay on *The Figure of the Earth.*

By the time William Thomson had reached his fifth year at Glasgow he turned his attention to physics, in which branch of science his genius had already shown.

He left Glasgow without taking a degree, and then went to Peterhouse College, Cambridge. In 1845 he was second



LORD KELVIN

wrangler, but in the competition for the Smith's prize, a sterner struggle, he succeeded in beating the senior wrangler.

The same year, anxious to gain laboratory experience, Thomson went to Paris and at the University worked in the laboratory of Regnault for four months. On his return to Cambridge in the autumn, he was elected a Fellow of his College and became a junior lecturer in mathematics.

At twenty-one Thomson had already studied in three universities, and achieved a reputation as a brilliant mathematician and physicist. Indeed, so highly was he thought of in the educational world that at twenty-two he was offered the Professorship of Natural Philosophy at Glasgow.

With little proper equipment, Thomson started a Physics

Laboratory at Glasgow University and soon gathered round him a band of enthusiastic workers. He had the happy knack of endearing himself to his students, partly by his keenness and partly by his sympathetic understanding. His fame spread throughout the University and soon reached the outside world.

Thomson was a terrific worker, and by the time he was twenty-six had published fifty original papers. It was in 1848 that he met James Prescott Joule at a meeting of the British Association at Oxford and there began a friendship that was to last for many years.

Joule was investigating the relations between heat, electricity and mechanical work, and his views so appealed to Thomson that he co-operated with Joule in his research. The result of this partnership was the publication in the *Transactions* and *Proceedings* of the Royal Society of their discoveries which laid the foundations of the science of thermodynamics.

In 1851 Thomson presented the Royal Society of Edinburgh with a paper on the dynamical theory of heat in which the principle of the dissipation of energy, briefly summed up in the second law of thermodynamics, was first stated.

To the world in general Thomson was best known for his work in the field of electricity, mainly in its application to submarine telegraphy. It was his brilliant mathematical analysis on electric oscillations which formed the basis of wireless telegraphy.

Thomson, while investigating cable-laying for the Atlantic Telegraph Company, invented the mirror galvanometer, the siphon recorder and the curb transmitter. The Society of Telegraph Engineers elected him their President.

Throughout his life he was a believer in the application of science to practical work. It was his aim that the mechanic who worked with tools and machinery should be taught practical science and be given the opportunity of learning the reason for the operations he had to undertake. In Thomson's own words he considered that "the life and soul of science is in its practical application . . . many of the greatest advances that have been made since the beginning of the world have been made in the earnest desire to turn the knowledge of the properties of matter to some purpose useful to mankind."

To deal with the multiplicity of his work in a brief chapter is impossible. There seems no branch of science which did not interest him. He studied atmospheric electricity, and from his investigations was derived the adaptation of instruments for measuring electric quantities, so that when electric lighting

came into general use it was easy to produce the necessary instruments for electrical engineers.

It was Thomson who induced the British Association to set up the first Committee for the determination of electric standards. This was in 1861. Twenty years later he visualised the chance of using the power of Niagara Falls for generating electricity.

In 1873 he was asked to contribute a series of articles on the Mariners' Compass to *Good Words.* He wrote the first one and then, on further consideration of the instrument, he stopped the series while he undertook the entire reconstruction of the compass.

He also invented a sounding apparatus for taking soundings by use of a line of steel piano wire; a tide gauge, a tidal harmonic analyser and a tide predictor. He published a set of Tables for seamen and studied gyrostatics, and in 1871 the Admiralty appointed him a member of the Admiralty Committee on Designs of Ships of War. Later, he sat on the Committee of 1904–5, of which the deliberations resulted in vessels of the Dreadnought type.

In collaboration with his friend Guthrie Tait, Thomson prepared a book of natural philosophy which completely changed the whole system of teaching in that branch of science. His best known invention was, perhaps, the Kelvin Sounder in which the time of echo is recorded so that the seabed can be plotted almost instantaneously. It was, in a sense, the acoustical counterpart of radar.

Thomson received many honours. He was President of the Royal Society from 1890–1894. In 1892 he was raised to the peerage under the title of Baron Kelvin of Largs in the County of Ayr, and was one of the original members of the Order of Merit. Practically every foreign Academy was proud to have him as member and he held honorary degrees from every University of note.

He was twice married. In later years he lived mainly at his mansion at Netherhall, near Largs. His death occurred on 17th December, 1907, following on the effects of a severe chill.

In view of recent developments in the use of atomic power it is interesting to note that Kelvin refused to believe that the atom was capable of either division or disintegration.

THOMAS HENRY HUXLEY

1825–1895

THOMAS HENRY HUXLEY, British biologist and natural philosopher, was one of that group of 19th century scientists whose conclusions, arrived at through their own investigations, gradually led them to doubt current views, maintained by theologians, regarding the working of the laws of nature. The idea of evolution, like yeast in the dough, was constantly in movement in their minds, until, at length, it was publicly proclaimed in Darwin's *Origin of Species.*

As great a controversialist as a scientist Huxley was first and last a fighter, the battle being to "make things clear, to get rid of cant and shams of all sorts". In the struggle of the evolutionists versus the theologians Huxley took a leading part and referred to himself as "Darwin's watchdog".

Born in London in 1825 Huxley was the son of an Ealing schoolmaster. In his own words, his early education may be summed up as "two years of the pandemonium of a school between the ages of eight and ten".

When he was ten his father moved from Ealing to Coventry. But educational opportunities advanced very little for Thomas who, left to his own devices, developed a voracious appetite for reading books of all kinds and, in consequence, filled his head with a mass of information of every description.

Mechanical engineering, as is so often the case with boys, made a strong appeal to him, but later he inclined more and more to the idea of a medical career, and at fourteen was apprenticed to one of his brothers-in-law, a Dr. Scott, in practice in London.

It was while working with Scott that Thomas attended a post mortem and there contracted an unaccountable sickness which left him delicate for the rest of his life.

In 1842 he and one of his brothers obtained scholarships at Charing Cross Hospital and there started regular medical studies. In spite of his medical work, however, Thomas Huxley still found time to study comparative anatomy and read the main writings of great biologists. In fact, it was while working at the Hospital that Huxley published his first scientific paper demonstrating the existence of an hitherto unknown layer in the inner sheath of hairs which is now known as Huxley's layer.

1845 saw his graduation as M.B. and success in winning the Gold Medal for Anatomy and Physiology.

When qualified to practice his profession Huxley applied for an appointment in the Royal Navy and was subsequently entered on the books of the *Victory* for duty at Haslar Hospital.

While at Haslar he soon made his ability known and was offered the post of Surgeon to H.M.S. *Rattlesnake*, a naval vessel about to embark on a surveying trip in Torres Strait.

THOMAS HENRY HUXLEY

So as "a surgeon who knew something about science" Huxley sailed with the *Rattlesnake*, and like his great contemporary Charles Darwin while voyaging on the *Beagle*, made the most of his chances for research on this expedition.

Many were the papers on the marine surface life of the tropical seas that the young Surgeon sent back to the Linnean Society. These received little or no appreciation, but one entitled *Affinities of the Family of the Medusae* was printed in the Royal Society's *Philosophical Transactions* in 1849 and brought the name of Thomas Huxley to the notice of scientific men.

Returning to England Huxley found that the value of his work was recognised. The Royal Society elected him a Fellow in 1851, and in 1852 he was awarded the Royal Medal and

elected to the Council. He was named as one of England's top-ranking scientists and counted among his personal friends men such as Hooker, Tyndall and Darwin.

In order that he might carry on writing up his work on the *Rattlesnake* the Admiralty retained him as nominal assistant Surgeon. But when after three years he was ordered on active service, Huxley decided that rather than give up his research he would resign from the Navy.

This he did, regardless of the fact that he had no money and no job. Determined to try to make a living from writing Huxley seems to have had few qualms about the future. His optimism was justified for he was offered the post of Lecturer to the School of Mines in addition to being given the post of naturalist to the Geological Survey.

While in Australia with the *Rattlesnake* Huxley made the acquaintance of a Miss Heathorn. This friendship ripened into love and in 1855 the lady and her parents came to England and she and Huxley were married.

From this time onwards Huxley led an increasingly active and full life. His biological researches were to bring him into the forefront of British science. From 1864 to 1884 he served on ten Royal Commissions, he became Secretary of the Royal Society, and its President from 1881 to 1885.

In 1870 Huxley became a member of the newly constituted London School Board and devoted much of his time to furthering the cause of education. His work in this direction which was so near to his heart left a mark on national elementary education.

Huxley was a prolific writer and a brilliant lecturer and speaker. When teaching he adopted a method which became a model for all lecturers in biology. His way was to describe small series of animals which he chose to illustrate important types of structure. By this means it was possible for each student to test general statements by referring to some member of the group he had been taught about in detail.

It has been repeatedly stated by his detractors that Huxley attacked Christianity and all forms of organised religion. This is not the case. What he did fight throughout his life was ignorance and superstition. It was not the Founder of Christianity or His laws that were attacked but the prejudices of religion, and theologians and divines whom Huxley considered led people astray.

He wanted "to promote the increase of natural knowledge and to further the application of scientific methods of investigation to *all* the problems of life".

His ideal of religion is often quoted: "In the eighth century the Hebrew prophets put forward a conception of religion which appears to be as wonderful an inspiration of genius as the art of Pheidias or the science of Aristotle, and made that the Lord required all these people to do justly and to love mercy and walk humbly with God."

In 1892 Huxley became a Privy Councillor, honorary degrees poured in on him from Universities all over the world, and he was a member of countless foreign societies, besides undertaking administrative work in connection with the Zoological Society and the Ethnological Society.

His health, never robust, broke down in 1885 and in 1890 he left London to live at Eastbourne where he died on 29th June, 1895.

The free education offered to all children to-day in Britain and many other countries would have rejoiced the heart of Thomas Huxley who battled so strenuously to this end. "The only medicine for crime and suffering," he said, "and the other woes of mankind, is wisdom. Teach a man to read and write and you have put into his hands the great keys of the wisdom box. But it is quite another matter," he added, "whether he opens the box or not!"

Speaking to working men on science and education Huxley warned: "I want the working man to understand that science and her ways are great facts for him, and that he is to be clean and temperate . . . because these are plain and patent laws of nature which they may disobey only under penalties."

He wrote many books and scientific memoirs, the most popular with the lay public being his *Collected Essays* in nine volumes.

JOSEPH LISTER
(1st Baron Lister of Lyme Regis)

1827–1912

THE wonders of modern surgery are mainly due to the discovery of anæsthetics and the cause and prevention of sepsis, two of the most far-reaching occurrences in medical history.

Before the 1840s, in spite of Sir Humphry Davy's discovery of the anæsthetising properties of nitrous oxide, or laughing gas, doctors tried to deaden pain with various drugs. Alcohol was often used to produce insensitivity, eastern drugs, such as hashish, opium and even mandragora, were given, and in some cases hypnotism was attempted.

It was an American dentist who, in 1844, made the first use of laughing gas for a dental extraction, two years later ether was tested and found successful, and in 1847 an English Professor, John Simpson, discovered the remarkable properties of chloroform as an anæsthetic.

But great as were these three discoveries and the blessings they brought to suffering humanity, they did not cure or even prevent sepsis, and hospital mortality from amputations alone was frequently as high as eighty per cent.

A patient entering hospital to undergo an operation in the 18th and early 19th century had little chance of surviving the ordeal. Wards were conspicuous for their lack of cleanliness. Surgeons would operate dressed in filthy coats sticky with blood and pus. Lengths of silk and hemp for use in tying ligatures dangled from their grimy pockets. Instruments were not sterilised; the probe, a much used tool, was only washed occasionally and the nurses, frequently half tipsy, were as untidy and dirty in appearance as the surgeons. Little wonder that knowing the high percentage of deaths no one would risk an operation unless he or she felt morally certain they were already nearly dead!

Such was the state of the hospitals when on 5th April, 1827 there was born to a well-to-do merchant of Upton in the county of Essex a son, who through his great medical work was to become one of the benefactors of mankind.

Joseph Lister's ancestors were Quakers, and his father a man of scientific attainments who perfected the achromatic lens and improved the compound microscope.

Joseph was encouraged as a child to take an interest in natural history and to observe what went on around him. He attended Quaker schools in Hitchin and Tottenham, and even in his school days announced that he was determined to become a great surgeon.

From Tottenham he went to University College, London, and in 1848 started as a medical student at University College Hospital.

JOSEPH LISTER

Lister's earliest researches were physiological, dealing with the structure and functions of tissues. In 1852 he took his M.B. degree and also became a Fellow of the Royal College of Surgeons. His original work was attended with considerable success even at the outset.

Between the years 1853 and 1858 Lister published a series of pamphlets all connected with physiological problems, the most famous being that classic paper *The Early Stages of Inflammation.*

In 1853, anxious to gain wider experience, Lister, armed with an introduction from Professor William Sharpey, the English physiologist, journeyed to Edinburgh to meet the celebrated Scottish surgeon, James Syme.

At first a visitor, Lister stayed on to study Syme's methods and became a dresser and later house surgeon to Syme. Three years later he married Agnes Syme and accepted the post of assistant surgeon at Edinburgh Infirmary. In 1880 he was offered and accepted the Chair of Surgery at Glasgow University, and the following year was appointed surgeon to Glasgow Infirmary.

During the busy years that followed, Lister's researches led to those discoveries which brought him fame and saved so many lives.

While he visited the Infirmary wards he would watch with distress the apparently inevitable deaths that followed on operation after operation. His observations eventually brought him to the conclusion that it was the influence of the atmosphere on open wounds that caused the dreaded septic diseases. He noted that in a fracture where the skin was not broken the bone would heal, and the patient suffer little ill effects, but where air reached a wound then trouble was almost certain.

Why should this be? Day after day, night after night, did Lister tussle with the problem, but the solution seemed no nearer. Then, in 1865, one of his hospital colleagues drew his attention to recent researches of the Frenchman, Louis Pasteur, who had proved that putrefaction was due to microbes growing in the putresible substance of wounds and coming from the air itself.

Reading an account of Pasteur's work a great light broke upon Lister. Here at last, he thought, was the key to the riddle. As a result of his own researches it now seemed clear that the destructive germs must themselves be destroyed if the patient was to survive.

He decided to use a chemical agent, carbolic acid, and in March 1865 employed this method when treating a compound fracture. Early the next year he carried out the same treatment on a fractured leg with equal success. The fracture healed and the patient recovered.

Lister was jubilant, and this case was used in the account written by him to the *Lancet* under the title of *A New Method of Treating Compound Fractures, etc.*

The medical world was agog. In France and Germany Lister's methods were wholeheartedly supported, but in England his campaign progressed but slowly.

He early abandoned the carbolic acid spray first used to destroy germs on wounds. He realised that a better method was to try to prevent them ever entering by insisting on scrupulous cleanliness in wards, instruments, clothes, person,

and dressings, and by keeping the air as germ-free as possible.

Lister spent many years experimenting with ligatures and, finally, was led to accept catgut in place of the old-fashioned hemp and silk.

In 1877 he accepted the Chair of Clinical Surgery at Kings College, London, a post he held for fifteen years. He became a Fellow of the Royal Society in 1860 and its president from 1894–1900. He was also President of the British Association in 1896.

A Baronetcy was conferred on him in 1893, and in 1897 he was raised to the Peerage and became one of the twelve original members of the newly constituted Order of Merit in 1902.

As Sir Joseph Lister he was instrumental in founding the British Institute of Preventive Medicine.

On his eightieth birthday Lister received the freedom of the City of London, a signal honour bestowed only for great public service. After a long life spent in the service of humanity Lister died at Walmer in 1912 and was buried beside his wife in West Hampstead Cemetery. The nation hoped that he would lie in Westminster Abbey, but it was his express wish to be laid close to Lady Lister, who predeceased him.

The value of Lister's work is almost incalculable, for he made it possible to conquer the four dread surgical diseases of erysipelas, pyemia, septicemia and hospital gangrene.

JAMES CLERK MAXWELL

1831–1879

WITH the death of James Clerk Maxwell in 1879 at the early age of forty-eight the world lost one of its most brilliant mathematicians and physicists, a man who for more than half his life was an acknowledged leader in natural philosophy, and who, when only fifteen years of age, was communicating scientific papers to the Royal Society of Edinburgh.

The major work of Maxwell's life was devoted to electricity. He had the great good fortune to know Michael Faraday personally, and it became Maxwell's endeavour to show "how by strict application of the ideas and methods of Faraday the connection of the very different order of phenomena which he discovered may be placed before the mathematical mind".

Prior to 1850, scientists believed that there must be some intimate relationship between magnetism and electricity, and by that time electromagnets and galvonometers were already in use. It fell to such men as Faraday, Kelvin, and Maxwell to work out the theory of this relationship and to lay the foundations for the many practical applications we know to-day.

James Clerk Maxwell, who was born in Edinburgh on 13th November, 1831, was the last representative of the branch of a highly esteemed Scottish family of Clerk of Penicuik. His father had added the name of Maxwell on inheriting a small estate in Kirkcudbrightshire.

James was educated first for seven years at the Edinburgh Academy, and then at the University up to 1850 in which year he entered Cambridge. He spent two terms at Peterhouse College and then transferred to Trinity.

In 1854 he took his degree as second wrangler, and in the examination for the Smith's Prize was declared equal with the senior wrangler of his year.

His remarkable genius for mathematics developed at a very early age, and while still at the Academy his paper entitled *A Mechanical Method of Tracing Carthesian Ovals*, so impressed one of the professors that he communicated it to the Edinburgh Royal Society. Maxwell contributed two other papers to the *Transactions*, one on the *Theory of Rolling Curves*, and the other on the *Equilibrium of Elastic Solids*.

On taking his degree Maxwell read a paper on the *Trans-*

formation of Surfaces by Bending, and about the same time produced his brilliant memoir *On Faraday's Lines of Force*. It was in this latter work that there appeared the first signs of Maxwell's researches into electricity which were to bring him fame.

On leaving Cambridge Maxwell was appointed to the Chair of Philosophy in Marischal College, Aberdeen, which he held until 1860 when he left to take the Chair of Physics and Astronomy at Kings College, London.

JAMES CLERK MAXWELL

After holding the post at Kings for eight years Maxwell resigned and retired to live on his estate at Glenlar.

He was not, however, to stay long in retirement, for in 1871 he was elected to the newly created professorship of Experimental Physics at Cambridge which he held until his death.

One of Maxwell's first tasks on taking up his new appointment was the superintendence of the plans and building of the now famous Cavendish Laboratory, designed in honour of the scientist Henry Cavendish, whose kinsman and founder of the laboratory was the Duke of Devonshire, Chancellor of the University.

Maxwell was a great admirer of Henry Cavendish's work, and at the time of his death was engaged in editing the collected Electrical Researches of the earlier scientist

During 1855 and 1872 Maxwell published the results of his investigations into the *Perception of Colour and Colour Blindness*, for which he received the Rumford Medal in 1860. He investigated the effects of the various combinations of colours by means of the rapid rotation of discs, differently coloured in different parts. His colour top is well known.

One of Clerk Maxwell's greatest researches bore on the Kinetic Theory of Gases, and he derived the law of distribution of velocities of the molecules of a gas, which came to be known as Maxwell's law. He also wrote an excellent textbook, *The Theory of Heat*, and a treatise on *Matter and Motion*.

But Maxwell's best work was that related to electricity and magnetism, and his theory in its fully developed form was published in 1875 in his treatise, *Electricity and Magnetism*.

Much of the work that led to this publication began while Maxwell was still an undergraduate. Drawn to Faraday and his work he studied this with the closest attention. Faraday in his electrical research had come up against the old problem of what universal medium was used through the phenomenon of electricity and magnetism expressed themselves.

Faraday believed that there was such a medium throughout space and that it might well be the same through which light waves were transmitted. He demonstrated that electricity, light and magnetism were inter-related, but did not explain in what way.

The task that Maxwell set himself was to clarify, as it were, the suggestions of Faraday, and to prove, if possible, that what Faraday believed was actual fact.

At length, through expert mathematical analysis, Maxwell was able to prove that electro-magnetic disturbances and waves of light are transmitted by one and the same medium, and at the same speed. He showed that the oscillations in the ether which, when reaching our eyes, enabled us to "see", consist of successive beats of a force similar to that force which causes what we know as a "magnetic field".

We might well remember when we turn on our radio to hear the news, or "look-in" to the latest television programme, that by his brilliant mathematical calculations James Clerk Maxwell predicted the discovery of wireless waves, later made by the German, Hertz.

Fundamentally, all were radiations, X-rays, Gamma rays, ultra violet rays and radiant heat are the same. Maxwell produced an equation of the electro-magnetic field which applied to light as well as electro-magnestism. He showed that light waves are short electro-magnetic waves.

Maxwell was only forty-eight when he died at Cambridge on 5th November, 1879, to be deeply mourned by his friends and pupils. In private life he was greatly beloved. His character was kindly and sympathetic and he was never too busy to give a helping hand to a student who needed it.

Shams and falsehoods were anathema to his upright nature. His religion was an integral part of his daily life, and he was known when lecturing to state his expression of faith in "Him Who in the beginning created not only the heavens and the earth, but the material of which heaven and earth consist".

SIR WILLIAM CROOKES, O.M.

1832–1919

William Crookes was one of the most versatile of British scientists, and had developed to an extraordinary extent that devouring curiosity for finding out that so often distinguishes the man of science from his fellows.

He was born in London on 17th June, 1832, the first child of his father's second marriage. It is recorded that he inherited from his father, a tailor who had left a Northern home to make a considerable fortune in London, a strong character, intellectual ability and great tenacity of purpose. From his mother came his handsome appearance and charm.

William Crookes went first to school at Chippenham Grammar School, then, when he was sixteen, he studied chemistry at the Royal College of Chemistry and became an assistant under the famous Hofmann.

Six years later, in 1854, he took a post in the meteorological department of the Radcliffe Observatory at Oxford. This, however, was of short duration, for the next year, after a brief period in a chemical post at Chester, he married a Miss Ellen Humphrey and moved to London, where he devoted himself entirely to writing and scientific research.

Crookes was the founder of the *Chemical News*, a journal which he edited and ran on somewhat novel lines for many years.

It was in 1848, while at The Royal College of Chemistry, that Crookes wrote the paper on the seleno-cyanides which led to his being offered the post of laboratory assistant. Many years later, after Bunsen had made use of the prism spectroscope for the investigation of volatile elements in flames, Crookes employed similar methods for examining the sources of selenium used in his earlier research. While carrying out this examination he discovered the hitherto unknown green line in the spectrum which led to his isolation of a new element, thallium.

By this discovery Crookes established his reputation as a research chemist. A specimen of thallium was first shown publicly at the 1862 Exhibition and in 1863 he was elected a Fellow of the Royal Society.

Further investigation was carried out along similar lines by Crookes and in 1872 he communicated a paper to the Royal

Society in which he gave an account of his previous experiments, together with the atomic weight of the metal thallium. His work in this respect was an extremely meticulous and delicate piece of research. He described the first vacuum balance and showed that the high degree of accuracy obtained was accomplished by employing the knowledge that if a nearly poised balance is enclosed in a partly evacuated container a

SIR WILLIAM CROOKES

portion may be chosen where the difference in weight of the two sides of the balance brings about an exact equipoise.

While investigating the properties of thallium Crookes observed the erratic behaviour of the hot element while measured in vacuuo. It was this that led to his invention of the radiometer, an interesting device in which a series of vanes, each blackened on one side and polished on the other, revolve rapidly when exposed to radiant energy.

His two main lines of research were on the properties of rarefied gases and the investigation of raw earths.

Crookes was led to the study of radio-activity and he invented an instrument called the spinthariscope, consisting of a zinc sulphide screen which indicated traces of radium salt by producing phosphorescence which is clearly visible to the observer.

An investigation was begun by Crookes in 1883 into the nature and constitution of certain rare earths and his examina-

tion of yttrium brought him to the conclusion that all elements have been evolved from one primordial substance.

Crookes was so highly thought of that he was frequently consulted by the Government on chemical matters. One of his later investigations was into the production of some form of transparent glass that would be effective in protecting the eyes of factory and other industrial workers. This resulted in a type of lens which shielded the eyes of glass workers from dangerous rays and transmitted only the useful rays of the spectrum.

Among his many other researches Crookes investigated the use of disinfectants, the many problems connected with wheat growing and the making of artificial diamonds. He also carried out the separation from uranium of its active transformation product, uranium-x.

Crookes published many papers on spectroscopy and wrote various technical books, including a treatise on Select Methods in Chemical Analysis. The Crookes tube is an early form of gas filled X-ray tube of the focus type invented by him and during his researches into electrical discharges through rarefied gas he discovered the "dark space" which now bears his name.

He was President of many learned Societies; the Chemical Society, the Institution of Electrical Engineers, the Society of Chemical Industry, the British Association and the Royal Society. He was knighted in 1897 and received the Order of Merit in 1910.

Originality and skill in carrying out research are the most outstanding traits in Crookes's character; these and his insatiable curiosity. He was for many years an interested student of psychic phenomena which he attempted to correlate, in some way, with ordinary physical laws.

When his wife, whom he loved most deeply, died in 1917, Crookes did not long survive her. He died in 1919 at the age of eighty-seven after a life spent almost wholly in scientific research.

WILLIAM HENRY PERKIN

1838–1907

UP to 1860 the comparatively few dyes available for ordinary use were obtained from roots, bark, berries or animal products. The thousands of shades seen in modern textiles were unknown, those mainly used being the pinks of madder, indigo, and the famous Tyrian purple from a small shell-fish found on the shores of the Mediterranean.

The first step in the development of the modern dye industry was the accidental discovery of an aniline dye made by a young British chemist, William Henry Perkin, in 1856, which led to the addition, by chemical synthesis, of many thousand synthetic dyes.

Like many other "chance" scientific discoveries that have benefited mankind, Perkin's investigations opened to the world new sources of wealth and advancement and made possible the range of exquisite shades now obtainable in the modern dye industries.

Born in London in 1838 William Henry Perkin was son of a well-to-do builder and contractor. The boy had intelligence above the average and showed that marked trait of the scientist, an enquiring mind. He was always eager to know the whys and wherefores of all he saw.

It is related that when shown a collection of crystals for the first time he was so entranced by their beauty that he then and there made up his mind to become a chemist when told that chemists had to study these things.

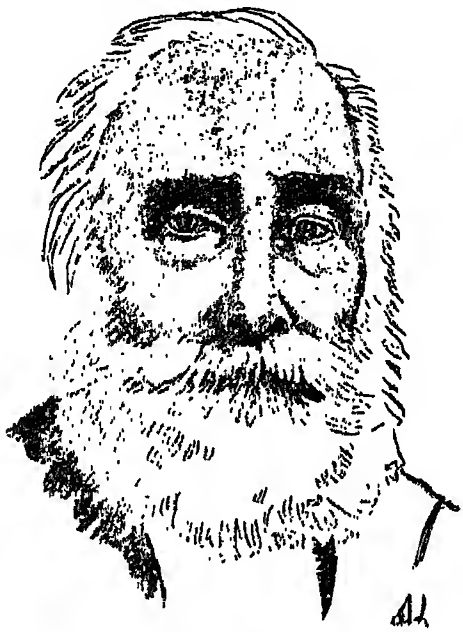
Although of opinion that the boy should learn the building trade, the elder Perkin soon found that William's heart was set on a scientific training. At the City of London College which he attended he got much encouragement from one of the masters, Thomas Hall, himself a scientific enthusiast, who did all he could to foster his pupil's talent.

Day after day Mr. Perkin was badgered and bothered to let William go to the Royal College of Chemistry on leaving school. His refusals were ignored—at last the boy's earnestness won the day. The building profession lost an apprentice and a new world of science opened its doors to yet another devotee.

At the Royal College William Perkin studied under the Director and Head, August von Hofman, an indefatigable

worker and a man who would always help those who were keen and studious.

Perkin needed little inducement to work. He soon attracted Hofman's notice, and at sixteen was made laboratory assistant. Not content with the hours spent at the College, Perkin rigged up a laboratory in his own room and would spend all his spare time working with test tubes and retorts.



WILLIAM HENRY PERKIN

It was during one Easter holiday, the year 1856 to be exact, that Perkin decided to put in some work in the laboratory experimenting in an attempt to obtain artificial quinine from coal tar, after a suggestion made at some time or other by Hofman. Coal tar, the heavy oily substance left when gas has been distilled from coal was, in those days, considered a useless waste product.

As he bent over his work Perkin peered down into the test tube and noted a dark mass at the bottom. "Strange," he thought, and dropped some water over it. To his astonishment there appeared a fine purple shade to the liquid. He picked up a bit of cotton waste from the bench and dipped a strand into the water. There it was—a beautiful purple, like the royal hue of the ancients; the first recorded result of aniline dye!

Perkins could scarcely believe his eyes. Rapidly, he reviewed the process. He had made aniline from coal tar, oxidising it with potassium bichromate and thereby obtaining the dark thick residue which gave the dye. He tested the stuff again, yes, the result was the same—a glorious royal purple.

Even to-day it seems incredible that from black, sticky tar should come the world's most exquisite colours, the finest perfumes, many medicines and various things used in our everyday life. Even with his chemical knowledge, the full significance of his discovery was not grasped by Perkin.

It should be remembered that these dyes, scents and medicines are not found ready-made in coal tar. Many chemical processes have to be carried out. There are certain crude compounds directly obtained from coal tar which are convertible by chemists into more complex materials, and it is these latter which are the raw stuff from which dyes are produced.

Aniline is one of these raw materials and it was from this that Perkin found his new dye. Aniline is a colourless, odourless dye, existing in benzol, which, in turn, is found in the gas given off when soft coal is heated without air. The purified benzol is first treated with nitric acid to yield nitro-benzene and this is converted to aniline.

Perkin advised Hofman of his experiment and took other expert advice, for he believed that if he could only commercialise his work it would be of enormous value. His father, brother, and Hofman gave all the help possible, the process was patented and a factory planned.

After receiving favourable reports on the dye from such reputable firms as Pullars of Perth, Perkin resigned his post at the Royal College of Chemistry and set up his own factory at Greenford, in the county of Middlesex.

The going was far from easy at first. Perkin found that he actually had to manufacture his own raw materials and equipment before work could begin. But he set to work and after he had the necessary materials, within six months he was manufacturing purple dye in commercial quantities under the name of Aniline Purple, or Tyrian Purple. The name later given to it in France was "mauve".

From the original dye Perkin went on to make Turkey Red and other shades, and at the age of twenty-three he was lecturing to the leading English chemists.

Until 1873 Perkin held almost the entire English dye market. Honours came to him from all parts of the world. He not only made money but received great international fame. But

his was the true scientific nature. Research was his work and money-making of little consideration. When he was thirty-six he transferred his whole business to Brooks, Simpson and Spiller and retired to devote the rest of his life to original research.

During the years that followed Perkin made many important chemical discoveries. On the jubilee of the discovery of aniline purple in 1906, he was knighted. But in the next year, on 14th July his death took place at Sudbury, Middlesex, close to the place where his factory had first been built.

Perkin was twice married and left three sons and four daughters to mourn their loss.

ALEXANDER GRAHAM BELL

1847–1922

"COME here, Mr. Watson, I want you."

Simple words, but now famous, for they comprised the first complete sentence ever spoken across a telephone wire, and thanks to the genius who made this possible, almost throughout the world men to-day can speak to each other, and whole nations have been brought into mutual contact. The seeming miracle of seventy-one years ago is now a commonplace of everyday life.

One hundred years ago, on 3rd March, 1847, Alexander Graham Bell was born in Edinburgh, and to celebrate his centenary an Association was formed in London to establish scholarships in universities and to raise funds for founding the Alexander Graham Bell College of Electricity and Physics to be attached to Edinburgh University.

The talents of his father, Melville Alexander Bell, and his grandfather, both well known authorities on elocution and phonetics, crystallised in the genius of Alexander. From his earliest days the boy heard discussed their work on behalf of deaf people, and so apt a pupil did he become that at sixteen he knew enough to give lessons himself. In his imaginative mind was implanted the burning desire to help his fellow creatures which through life remained his greatest aim.

After graduating at the Royal High School, Edinburgh, Alexander went on to Edinburgh University and later to London University, where he matriculated. For a short time he taught elocution and music at a school in Elgin and then assisted his father in teaching a system of visible speech which interpreted in symbols the sound of the human voice.

In 1867 Melville Bell was offered a post at London University and the family moved from Scotland. In London, Alexander continued to help his father and already had determined to try to design an instrument that would help the deaf by making sounds visible. His work showing deaf mutes how to use throat and speech organs was already recognised as of great value.

But a bitter blow fell on the Bell family. Two of Alexander's brothers contracted tuberculosis and died, and his father was informed that unless Alexander was sent to a more suitable climate his life, too, was not worth six months purchase.

The work in London was abandoned and the home broken up. With heavy hearts Mr. and Mrs. Bell and Alexander left for Canada, where they settled on a small estate at Brentford, Ontario.

As it turned out the move was all to the good. Alexander's health rapidly recovered and he and his father continued their work in Ontario. Business connections in the United States

ALEXANDER GRAHAM BELL

helped Alexander, now fit and strong, to obtain a post as teacher at a Boston school. A year later he was appointed Professor of Vocal Physiology in Boston University.

While lecturing on visible speech in Boston he met two men who later were to give him a helping hand. Both these men had deaf children, both came to Bell to seek his advice. One was lawyer G. G. Hubbard, the other a rich leather merchant, Thomas Sanders.

For three years Alexander Bell lived with the Sanders family

in order to teach their small, deaf son. At the Hubbard home he was introduced to Mabel Hubbard who had been deaf from childhood, and with whom he eventually fell in love and later married.

His theory of the telephone was formulated during a vacation at Brentford with his parents. Two things were uppermost in his mind. To work at finding a system of multiple telegraphy, and to study air waves in the human ear during utterance of voice sounds. Actually, his invention of the telephone came from his research in these two directions.

To help set up apparatus Bell was fortunate enough to secure the services of a clever mechanic, Thomas Watson, and together they made devices for helping the deaf. Bell's idea was to try to show deaf people how recorded vibrations of the sounds they made compared with records of standard vibrations.

His first patents were for a multiple telegraph. This consisted of sets of reeds connected by a wire. One set of reeds of different vibration periods acting as a transmitter to another set which acted as receiver and vibrated only to sounds from the transmitting reeds.

Discovery of the electric telephone came almost by chance. Bell was working on the harmonic telegraph when Watson touched one of the reeds in order to try and send a vibration to Bell, who was upstairs.

Bell, whose ear was exceedingly accurate, caught the overtone of the reed. He realised at once that an instrument that could produce both the tones and overtones of a reed might also be made to transmit the vibrations of a human voice.

All other work was laid aside. The energies of the two men were devoted to perfecting the new discovery. In 1875 a rough model was built and the next year that first now famous request to Watson was sent by its aid. Bell was eventually granted a patent No. 174465 which proved to be worth a fortune.

A partially successful telephone conversation between Bell in Boston and Watson two miles away at Cambridge, took place in 1877, after Bell had demonstrated the instrument at the International Centennial Exhibition at Philadelphia. For the first time in history the human voice was made to carry over a considerable distance.

Described by Watson, the mechanism consisted of a wooden frame on which was mounted one of Bell's harmonic receivers, a tightly stretched parchment drumhead. To the centre of this the free end of the receiver was attached to a mouthpiece arranged to direct the voice to either side of the drumhead.

This was designed to make the reed follow the voice vibrations and generate "voice-shaped" electrical movements.

At first, Bell found it hard to interest anyone in his invention. When he showed it in a side booth at the Centennial Exhibition visitors were more amused by the earnestness of the dark-haired young demonstrator than interested in the apparatus. But there were exceptions. Sir William Thomson, the British scientist, later Lord Kelvin, declared it was the finest thing he had seen in America, and the Emperor of Brazil was so impressed with the demonstration that he brought the instrument to the notice of the Exhibition Committee.

Bell tried vainly to interest business men in his telephone, but far from interesting them he was actually attacked on the grounds that he was not the inventor, and became involved in hundreds of law suits before his claim was finally legally established.

His marriage to Mabel Hubbard took place in 1877 and the couple travelled to England on their wedding tour. In London, Bell gave a demonstration before Queen Victoria, who showed interest in the device and accepted a pair of ivory telephones made specially for her.

Londoners were so intrigued by the new invention that they were willing to pay as much as one penny to speak over a telephone to a man standing at the top of a City Church, in spite of the fact that the previous year the *Times* had denounced Bell's discovery as "An American humbug!"

In 1879 the first telephone exchange opened in London with seven or eight subscribers, and companies were set up in different parts of the country. However, in 1880, the Post Office declared that the telephone system was legally a telegraph system within the meaning of the Act of Parliament, and the Bell system became a monopoly of the Postmaster General.

When Bell returned to America the Western Union, who had bought the patents of one of his rival inventors, Elisha Gray, engaged Edison to design a transmitter for them, and there were therefore two companies, the Electric Telephone Company, formed by Bell, and the American Speaking Telephone Company. Eventually, to the advantage of both, the two Companies merged, and Bell soon found himself a wealthy man.

With his invention now established, Alexander Bell returned to his work for the deaf, and to other scientific research.

He was awarded the Volta prize of 50,000 francs from the French Government and with this he financed the Volta Laboratory at Washington, later to be known as the Volta Bureau for the Diffusion of Knowledge for helping the Deaf.

He also worked for the American Association for promoting the teaching of speech to deaf persons.

Eugenics interested Bell greatly and he was Honorary President of the 2nd International Eugenics Congress. He started *Science*, the organ of the American Association for the Advancement of Science and was also President of the National Geographical Society.

In his later years Bell turned to work on aeronautics. He designed and had built enormous kites, one of which forty-two feet long, rose in the air and carried a passenger. He also produced a glider that made a first flight in 1908, and designed a motorboat in World War I. which travelled at over seventy miles per hour.

Although an American citizen for many years (he was naturalised in 1874) Bell never forgot his native land, Scotland, but during the last twenty years of his life spent his holidays at his home in Nova Scotia. Among his many inventions was an instrument for detecting metal in the human body, used to trace the bullet after President Garfield had been shot, and a device by which the smallest difference in light is made to make a sound.

With his intelligence and genius unimpaired, beloved of all who knew him and as always with the desire to help the deaf nearest to his heart, Alexander Graham Bell died at his home in Nova Scotia on 2nd August, 1922. He was a great and kindly man as well as being a great scientist.

SIDNEY GILCHRIST THOMAS

1850–1885

"If the usefulness of an invention is to be measured by its creation of wealth then Thomas must rank as one of the greatest creators of wealth of the nineteenth century."

The man of whom these words were written was Sidney Gilchrist Thomas, a young British inventor who, before he was thirty-five, had been acclaimed as the genius who had solved a problem that had beaten the best brains of his time; that of the dephosphorisation of iron ore.

Britain had been slow to recognise the worth of Sidney Gilchrist Thomas, but on the Continent and in the United States he was hailed as a great inventor. His discoveries helped Germany to become a great industrial power, and in one decade German steel output was doubled, thanks to his process. So grateful were the Nazis that they claimed Thomas as a German and one of their country's benefactors.

In France his name is still honoured. In 1932 the Société des Ingenieurs Civiles de France organised a festival to celebrate the Jubilee of the introduction of Thomas's basic process. Scientists read papers on his work and tributes were paid at his graveside at Passy. Luxembourg, Belgium and Austria also hold him in high esteem.

Sidney Gilchrist Thomas was the second son of a Welshman who worked at the Inland Revenue Office, Somerset House, London, his mother being the daughter of a clergyman, the Rev. James Gilchrist.

Sidney was educated at Dulwich College where he distinguished himself by his intelligence and aptitude for learning. At fifteen he had passed his matriculation examination "first in the United Kingdom".

Science grew to be his keenest subject and it was his father's wish that he should try for a scholarship at Oxford or Cambridge with the idea of taking up science as a career. But Sidney thought otherwise, and in spite of his love of science decided to matriculate at London University and study medicine.

However, this was not to be. His father died when Sidney was seventeen and all hope of a University and medical career was abandoned. It became Sidney's aim to obtain a Civil

Service post in order that he might contribute to the support of his mother and sister.

While waiting for a Civil Service nomination he took a post as assistant master at an Essex school until, in 1867, he obtained a junior clerkship in the Metropolitan Police Courts. For a short time he was attached to the Marlborough Street Court and was then transferred to the Thames Police Court, Stepney.

SIDNEY GILCHRIST THOMAS

His work in the Courts brought Sidney Thomas into contact with a side of life hitherto unknown and unimagined. Its effect on him was profound and it imbued him with that desire to help his less fortunate fellow men and women that was one of the guiding principles of his life.

Although engrossed by day in his Court duties Thomas carried on his scientific studies in his few leisure hours. He attended lectures at the Birkbeck Institute and the laboratories of various teachers of chemistry, and passed examinations of the Royal School of Mines.

It was while attending lectures at Birkbeck Institute that he first determined to try to solve the problem of dephosphorisation of iron. A lecturer, speaking of the Bessemer converter, men-

tioned that the man who eliminated phosphorus in the Bessemer converter would make his fortune. The phrase stuck in Thomas's mind and he resolved, if possible to be that man.

The problem was apparently insoluble. Briefly, in the Bessemer process which converted pig-iron into steel, phosphorus, a common impurity of iron ores, was not dissolved, and in consequence the steel became brittle and useless so that only non-phosphoric iron could be used.

To prevent this formation of phosphorus in some way became Thomas's purpose. He visited iron works in England and abroad when on holiday, and in 1875 he felt in his own mind that, in theory at least, he had found a remedy.

It was his conclusion that the answer to the problem lay in the lining of the converter. He found that it was the chemical character of the lining, always of a silicious sort, that prevented elimination of the phosphorus. During the Bessemer process of conversion the pig-iron formed phosphorus which would not combine with the acid of the lining. This being the case, Thomas believed that a change must be made in the lining's chemical make-up.

He carried out numbers of experiments on linings of different types till at length he decided on one of lime or its congeners, magnesia, magnesium, limestone, etc. His idea was to separate the phosphorus from the iron and to preserve it in the form of phosphoric acid by creating a basic slag.

Eager to test his conclusions on a larger scale than was possible in his own attic laboratory at home, Thomas approached one of his cousins, Percy Gilchrist, a chemist attached to a large works at Blaenavon, South Wales.

Gilchrist was interested in Sidney's work and consented to help him with further experiments. By November 1877 they were convinced of their success and Thomas took out his first patent. The May following the complete specification was filed and from that date many more were to follow.

It was in March 1878 that the new process was first given out in public. But like so many other notable scientific discoveries, it received little encouragement.

Sidney Thomas attended, as a visitor, a meeting of the Iron and Steel Institute at which a paper was read on the separation of phosphorus from pig-iron in a furnace lined with iron oxide. Towards the end of this meeting Thomas managed to make a very brief statement in which he said that: "It may be of interest to members to know that I have been able, by the assistance of Mr. Martin at Blaenavon to remove the phosphorus entirely by the Bessemer converter. . . ."

Sneers and some smiles met this claim by a young and unknown clerk, and no observation of any kind was made by the Institute.

Thomas was in no way deterred. He prepared, during the summer of 1878, a paper describing his process which he intended to send to the Iron and Steel Institute for their autumn meeting in Paris.

The paper, entitled the *Elimination of Phosphorus*, was actually left unread through "lack of time" but luckily part of it had already been sent to *Engineering* and distributed to members.

While visiting the Creusot Works in France, Thomas interested the manager of Bolckow Vaughan & Co's Works in Cleveland in his work, and on his return to England converters were erected at Middlesbrough and Thomas demonstrated his process with great success. News of the tests soon reached the Continent, and Thomas was hailed as the inventor.

The dephosphorisation of iron had been solved by Sidney Thomas by the substitution, in the Bessemer converter, of a durable basic lining in place of the former silicious one. This secured a highly basic slag at an early stage of the blow.

On the Continent the basic process had a phenomenal and rapid success. Foreign manufacturers vied with each other to procure rights, for with more than usual foresight Thomas had patented his work abroad as well as in his own country.

Finding that his scientific work was a full-time job, in 1879 Thomas resigned his Police Court work. He visited the United States in 1881 where he was hailed as a genius. In 1882 he became a member of the Council of the Iron and Steel Institute and in 1883 was awarded the Bessemer Gold Medal.

It was at the height of his fame that his health, never robust, suddenly declined. Lung trouble developed and he was obliged to travel abroad. In 1882 he started on a world tour, working as hard as his health permitted and at the same time fighting a losing battle against sickness.

In 1884 he heard of a cure for lung diseases given by an English doctor in Paris and in July of that year left Algiers for France. But he failed to derive lasting benefit from the treatment and on 1st February, 1885 he passed peacefully away.

For some time before his death Sidney Thomas had been working on another line of research, that of the utilisation of basic slag. In England the slag was looked upon as so much rubbish to be stacked as waste, carted, and dumped into the sea. In Germany, experiments had already been carried out by 1883 and the slag, ground to a fine powder, had been tried on the land as manure.

These tests were unknown except in Germany, but Thomas had for some time been convinced that this so-called waste product could be put to good use. In 1882 he was already working to purchase basic slag in large quantities, when he learned that German agents had contracted for the purchase of British basic slag, in quantities of thousands of tons over periods up to ten years.

Although so near to death Thomas continued to fight for the use of basic slag. In 1884 news was received of the success of the German method of using the slag in powder form applied direct to the earth and the new fertiliser began to be adopted by British farmers.

The name of Sidney Gilchrist Thomas is still comparatively unknown in Britain. Yet the result of his Basic Process was to revolutionise the world's steel production and to play a big part in the prosperity of the Empire.

Thomas was a man endowed by nature with a good sense of business, unwearying ambition and an extraordinary charm of manner. If he worked hard to succeed it was not for himself but to help others less fortunate. His fortune, after bequests to his mother and sister, was left to be devoted to helping the poor and needy. Worldly success meant little to him, but to wrestle with and conquer any scientific problem was a challenge he never failed to accept.

SIR OLIVER JOSEPH LODGE

1851–1940

Sir Oliver Lodge was Britain's grand old man of science. He was a brilliant mathematician, an inventor and discoverer, a popular lecturer and broadcaster, and, above all, a great-hearted, noble man who did all in his power to comfort those he knew to be in distress.

To the man-in-the-street he is remembered as one of the leaders of spiritualism in Britain, but to the scientist it is his original research and many scientific attainments that made his name famous.

Oliver Joseph Lodge was born at Penkhull in Staffordshire. He came of hardy stock. His father was a merchant of Wolstanton with eight sturdy youngsters around him, and was himself one of a family of twenty-five.

Until the age of fourteen Oliver went to Newport Grammar School. Then it was considered that he ought to learn the family business, that of sellers of potters' materials, and he was taken away from school.

Already the boy had shown signs of intellectual ability and an interest in science, but his father was set on his son following a business and not a scientific career.

While obedient to the family dictum, Oliver studied at evening classes and at home and was able to pass, first his London matriculation and then his intermediate examination in science with first-class honours in physics.

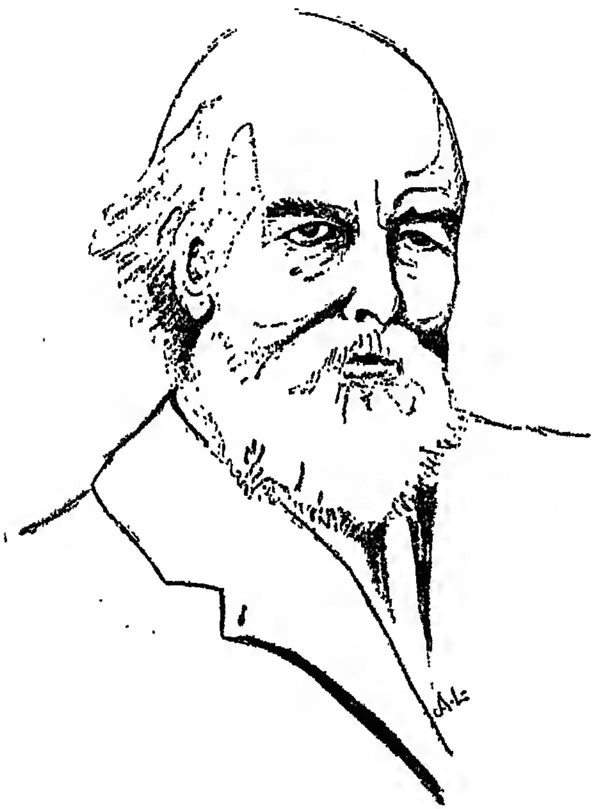
As it turned out, his business life was not to last for long. Just before he was twenty-three he was able to give up office work to attend University College, London, and there devote himself wholeheartedly to preparation for a scientific career.

For four years, from 1875 to 1879, Lodge worked as reader in natural philosophy at the Bedford College for Women. Then he became Assistant Professor of Applied Mathematics at University College, and a year later he was offered and accepted the Chair of Physics at University College, Liverpool, where he remained until 1900.

When the new Birmingham University came to appoint its first Principal the choice fell on Oliver Lodge, and in this post he worked up to 1919, when he retired from active University life. In addition to his scientific work Lodge was also an

excellent organiser and under his able guidance the University became an important part of the city's life.

His scientific investigations were extensive. He discovered Hertzian (radio) waves and invented and demonstrated the first practical wireless system. At Oxford, in 1894, he transmitted signals by radio waves to a distance of sixty yards. This was two years before Marconi filed his provisional specification



SIR OLIVER JOSEPH LODGE

for an apparatus for signalling by means of wireless waves. Lodge's discovery of making a detector resonate selectivity was in advance of Marconi.

In addition to many other contributions to physical knowledge Lodge carried out original research on lightning conductors, the movement of ions, the motion of the ether near the earth, the seat of the electro wave form in the voltaic cell,

and the application of electricity for the dispersal of fog and smoke.

After his death it was pointed out by another British scientist, Lord Rayleigh, that Lodge "was the first man to put electrical circuits into and out of resonance". The results of his experiments were later applied by Lodge to the first system of *tuned* wireless telegraphy of which he was the pioneer. This was a spark system which gave unlimited trains of oscillations like a tuning-fork when intermittently struck.

Lodge was a clear and able writer and published many scientific memoirs as well as longer works. Amongst these may be mentioned *Lightning Conductors and Lightning Guards*, *Signalling Without Wires*, *The Ether of Space*, *Ether and Reality*, and *Relativity*.

He was knighted in 1902 and honoured by degrees from the leading Universities in Britain. He received the Albert Medal of the Royal Society of Arts in 1919 for his pioneer work in wireless telegraphy, and the Royal Society, of which he was elected a Fellow in 1902, presented him with the Rumford Medal for his experiments in lightning conductors, his use of a coherer for detecting signals transmitted over 150 yards, and experiments disproving the existence of viscosity in the ether.

The Institute of Electrical Engineering awarded Lodge the Faraday Medal in 1932, and during his lifetime he acted as President of the British Association, the Physical Society, the Radio Society and the Röntgen Society.

No account of his long life can omit mention of Lodge's absorbing interest in spiritualism. After 1910 he became prominent as a leader of psychical research and publicly announced his belief in the possibility of communicating with the dead.

As a scientist he knew full well that in proclaiming this faith and making no secret of his research into psychic matters he would be scorned by many of his fellows. This, however, did not deter him, and he continued until the end of his life to preach his belief in survival after death.

His announcement of conversations which he claimed to have held with his son Raymond after the latter's death in the first World War, and his book *Raymond, or Life After Death* brought great publicity. His articles on spiritualism in the daily press and his public statements also kept him before the public eye.

But to men of science the name of Oliver Lodge will ever be most closely associated with his study of the ether and his valuable pioneer work in the field of wireless.

Lodge was filmed in 1934 and in front of the cameras he delivered a prophecy regarding the future of the world.

"Before the end of the twentieth or twenty-first century," he stated, "the ether will be recognised as the one means of communication between the atoms, and the whole of physics will become once more luminous and clear . . . we shall discover that it is the beginning and the end of things, that which lies behind and indeed makes possible the existence of our physical life and mind."

The film was not generally released, but after exhibition to all engineering and scientific Institutions was locked away for future reference.

He was happy in his family life. He had married in 1877 the daughter of one Alexander Marshall by whom he had twelve children, six sons and six daughters. His latter years were spent at his beautiful old-world home near Amesbury, Wiltshire, within walking distance of Stonehenge. For many years before his death Lodge had been working on methods of weather control and believed that one day science would be able to disperse or bring down rain at will.

He died in his ninetieth year on the 22nd August, 1940, and was buried next to his wife, who pre-deceased him, in the cemetery of the Wiltshire village of Wilsford.

THE HON. SIR CHARLES ALGERNON PARSONS, O.M.

1854–1931

The greatest development in steam practice that has taken place since James Watt took out his first patent for a steam engine in 1769 was the invention of the steam turbine by the Hon. Sir Charles Parsons.

Like his illustrious forerunner, who lived to see his engine used in many parts of the world, Parsons saw the British Navy and Mercantile Fleet revolutionised by the steam turbine which became prime mover for generating electricity in big ships and power stations.

Both the steam turbine and the reciprocating engine are driven by the kinetic energy of steam which carried energy from the fuel to the pressure-moved parts. In the reciprocating engine, however, the piston's up-and-down movement is turned into rotary motion by means of cranks, while in the turbine steam pressure is directly applied to the revolving shaft.

Charles Parsons was youngest and fourth son of the third Earl of Rosse, a man of scientific ability and famous as constructor of the large reflecting telescope at Parsonstown, Ireland.

As a boy Charles never attended school but was privately educated at home, where he had the benefit of hearing talk between his father and the many scientific men who visited the house.

Even as a lad Charles was interested in mechanics, and with one of his brothers managed to build a motor car that ran by steam on the road at ten miles per hour.

In 1873, after a short time at Dublin University, Charles went on to St. John's, Cambridge, where he passed eleventh wrangler in the Mathematical Tripos of 1876.

Leaving Cambridge Charles went as apprentice to the Armstrong Works at Elswick in order to get a practical working knowledge of metals and machines. While there he invented a four-cylinder rotary steam engine and carried out experiments with torpedoes gas-propelled by gas given off by burning rocket composition.

1883 saw him a partner in the firm of Clarke, Chapman and Company of Gateshead, at whose Works he built his first turbine.

Although his machines were not at first economical in steam consumption Parsons improved them and numbers were used for electric lighting.

Six years after joining Clarke and Chapman, Charles Parsons gave up his partnership and established his own Works at Heaton-on-Tyne.

Parsons's steam turbines for generating electricity had mainly

THE HON. SIR CHARLES ALGERNON PARSONS

been used on ships and thus came to the notice of marine engineers who, seeing their possibilities for propulsion, suggested to their designer that he might work to this end.

The result was that in 1897 Parsons produced the *Turbinia*, a small vessel of the torpedo-boat type which appeared during the Naval Review at Spithead and charged along the line of battleships. Although a picket-boat tried to stop her, *Turbinia* travelling at thirty knots easily out-paced her pursuer.

First vessel to be propelled by steam turbines the *Turbinia* was later improved, and in new form was fitted with three turbined and three propeller shafts and was the fastest vessel up to date.

After the appearance of the *Turbinia* Charles Parsons never looked back. The Admiralty was interested, very interested in

his turbines. Two torpedo-boat destroyers were fitted, then came the cruiser *Amethyst*, and in 1905, the "Special Committee on Design" advised the Admiralty to adopt it in the Dreadnought. Parsons's turbines became the standard method of propulsion for the British Navy.

After the Royal Navy the Mercantile Marine was not slow to follow, and steam turbines were fitted on many of the biggest and fastest steamers and liners.

Parsons next modified his turbines for use on smaller, slower boats by mechanical reduction gearing, and this was employed in 1912 on two cross-Channel steamers.

The new principle introduced by Parsons in his turbines in distinction to the reciprocating engine, was that a turbine should not consist of a single series of vanes round a shaft, but should be built with a great number of blades side by side, the steam being carried from one blade to the next, and introduced parallel to the shaft, not at right angles to its axis. The expanding steam as it moves through the turbine encounters larger and larger blades. From each blade it is deflected to a fixed blade on the casing from which it is deflected again at the correct angle on to the next blade. The blades are arranged in alternate rows of fixed and rotating series at the right angle to apply all the expanding force of the steam to the moving blades in the required direction.

This building-up of the force of the steam gives the enormous power of a large turbine plant with as many as 100,000 blades each giving its quota of energy to the shaft. Turbines are now built in huge units, twenty times the size of reciprocating engines, and are the largest power units in the world.

Besides his work on developing the steam turbine Charles Parsons made many other scientific and mechanical investigations. He took over the Derby Crown Glass Works and carried out research in optical glass, improving searchlights, and devising a method of constructing silvered mirrors to withstand the heat developed by the electric lamps in big searchlights.

He also made astronomical telescopes and invented a split reflector for use in the Suez Canal. This was specially built so that light could be given at the sides and not in the centre. Two halves were hinged so that the one or two beams, as required, could be set at any desired angle.

Charles Parsons received many honours. He was made a K.C.B. in 1911 and given the Order of Merit in 1927. He was a Past President of the British Association, the Institute of Physics and the North Eastern Coast Institution of Engineers and Shipbuilders, as well as occupying important posts on the

directorate of many Electric Supply and Engineering Companies.

He received the Rumford and Copley medals of the Royal Society of which he was made a member in 1898. He also received the Albert medal of the Royal Society of Arts, the Faraday medal from the Institute of Electrical Engineers, and the Kelvin medal.

Charles Parsons married in 1883, Miss Katherine Bethell, a founder of the Women's Engineering Society. He was a generous benefactor to science, leaving among other bequests, £3,000 to the Royal Institution and £2,000 to the British Association. He was a Governor of the Dominion Students Hall Trust for building a Hall of Residence in London for Dominion and British students. A Library called "The Parsons Library" in London House was erected to his memory.

It was said by those who knew him that Charles Parsons had an extraordinary gift of intuition which enabled him to judge accurately the worth of any scientific proposition. His power of concentration was great and he would go from his office to his workshop at home and stay there up to all hours of the night absorbed in some scientific problem.

He carried out many experiments on the effect of high temperatures and pressures on chemical action and the materials. It is stated that for twenty-five years he attempted to produce diamonds by pressure and then came to the conclusion that this could never be done.

He died on 12th February, 1931, while on a cruise in the West Indies, leaving a widow and daughter, his only son being killed in World War I.

The motto of "Parsons of the Turbine" was "Always keep on learning". In the first Parsons Memorial lecture delivered in 1936 by the Secretary of the Royal Society before the North-Eastern Coast Institution of Engineers and Shipbuilders, it was said that "the turbo-generator, the searchlight reflector, the marine turbine and the astromical telescope were not merely the products of Newcastle-on-Tyne"; they and many other inventions were essentially "the children of Charles Parsons".

SIR ALMROTH EDWARD WRIGHT
K.B.E., C.B.E., F.R.S., M.D.

1861–1947

WAR has for long been a testing ground for medical research. Under the impetus of war experiments and improvements are carried out in the course of a few months which, under ordinary peacetime conditions, would take many years. Conquests over disease on the battlefield have resulted in lasting benefits for the whole of mankind.

There died recently in Britain a medical researcher whose work, begun fifty years ago, at the Army Medical School, Netley, has been the cause of saving millions of human lives, both civil and military. This man was Almroth Wright, originator of the system of anti-typhoid inoculation for bacterial infections, known as vaccinotherapy.

Throughout his long life Almroth Wright was a hunter and destroyer of those deadly microbes that wage unceasing war on human beings. His success can easily be gauged by comparing the lives lost by typhoid fever before his discovery and methods of immunisation were available.

In the Boer War, except where Wright's methods were carried out, in face be it said of opposition from those in authority, more men died of fever than were killed in action. In the World War I. only half as much typhoid was recorded and only one seventh the number of deaths.

In the Franco Prussian war one German soldier in sixteen, it is stated, caught typhoid fever against a figure of one in every nine hundred of the British troops in World War I.

Almroth Edward Wright was son of a distinguished Irish clergyman and a Swedish mother. Educated on the continent and then at Trinity College, Dublin, he soon proved his high intellectual ability and won a gold medal in modern literature.

From Dublin Almroth Wright went to London where he began to study law, but, when later he gained a medical travelling prize, he discarded legal training for further studies on the continent where he stayed at Leipzig, Strasburg and Marburg, finally returning to Ireland to take his M.B., B.Ch. and M.D. degrees at Trinity College.

Medicine was his chosen career, and after indulging in original work at the Royal College of Physicians Wright was

offered the post of Demonstrator of Pathology at Cambridge in 1887.

A year later the opportunity arose to visit Australia through his acceptance of the Chair of Physiology at the University of Sydney. This post he held until 1892 when he returned to England to work as Professor of Pathology at the Army Medical School, Netley.

SIR ALMROTH EDWARD WRIGHT

Wright's interest had been aroused by experiments made on men suffering from cholera by inoculating them with bacteria, and by information published regarding cases of typhoid, also treated by inoculation. He determined to carry out detailed research into the subject of inoculation, and into the use of anti-typhoid vaccines.

A few years later, in 1896, Wright published the results of some of his experiments. The theory, on which his work was based, was that healthy blood may not have the germs neces-

sary to fight those attacking the patient, so he introduced bacteria into the patient's system to enable the deadly attacking germs to be destroyed.

At first, as is so often the case with original thinkers, his work met with a cold reception. But Wright was not the man to allow his work to suffer. He served on the Indian Plague Committee and did all he could to alleviate the frightful outbreaks of typhoid raging amongst British troops in India.

New methods of measuring dosage, preparing vaccines and determining the correct amount required for each patient were introduced by him. The results obtained by Wright during the South African War were good, and the same was also the case in India, once official opposition was overcome.

Wright left Netley in 1902 to take up the appointment of Pathologist at St. Mary's Hospital, London. There he created a special department of therapeutic inoculation, later renamed the Institute of Pathology and Research. Up to the last year of his life Wright visited St. Mary's to work in this department, and for forty years, so it is stated, drew a small amount of his own blood daily for experimental purposes.

During the first World War he served in France as consulting Physician to the British forces, and provided during the four years of war enough anti-typhoid vaccine for 4,500,000 persons.

He also worked on treatment of wounds and obtained satisfactory results by using solutions containing no antiseptics, in distinction to the Carrel-Dakin method which kept the wound continually in an antiseptic bath and drained away the pus.

That great British scientist, Sir Alexander Fleming, discoverer of penicillin, was a pupil of Almroth Wright, and it was in Wright's laboratory that the discovery of the "miracle" drug took place.

Many honours were given to Wright in his lifetime. Amongst these were Fellowship of the Royal Society and Fellowship of the Royal College of Surgeons in Ireland. In 1913 he was made a C.B. and in 1919 he was gazetted K.B.E. He was knighted in 1906.

Wright was a born fighter, a man who never ceased to wage war on the microbe killers of mankind. Amongst his many technical writings is found one quite untechnical paper. This is his attack on the feminist movement, entitled *The Unexpurgated Case Against Women Suffrage.* He was to the end of his life a violent opponent of woman's suffrage, although the kindliest of men and one friendly to all those with whom he came in contact

He was married and had one son and one daughter, but had been for many years a widower, his wife dying in 1926.

His work is now bearing fruit. It is mainly due to his untiring efforts that to-day diphtheria figures are low, and the incidence of typhoid in the forces almost negligible compared to those of the past. The whole world has reason to thank this great scientist, so rightly named "the pioneer of immunisation".

HERBERT GEORGE WELLS

1866–1946

"We have dreams; we have at present undisciplined but ever-increasing power. Can you doubt that presently our race will more than realise our boldest imaginations, that it will achieve unity and peace, that it will live, the children of our blood will live, in a world more splendid and lovely—going from strength to strength in an ever-widening circle of adventure and achievement. What man has done in his little triumphs of his present state, form but the prelude to the things that man has yet to do."

That message, of warning perhaps, but certainly of hope, was one of many left to us by that great Englishman, H. G. Wells, a prophet and a man whose faith was the belief that freedom of mind and soul is our only hope towards all advancement.

It is idle to pretend that we are not interested in the future, all of us. Prophecy was one of the first sciences. I admit that the present with its never-ending flow of scientific development is full of interest, but it is the future that most excites our imagination.

Wells was a visionary. All his life through, but with increasing clarity in later years, he looked for a Golden Age to come if man would but plan his future. He preached a single World Community, a new Final International as he called it, to "guide us on the next step towards a liberated and unified earth".

In his brilliant scientific forecasting, which is a very different thing from prophecy, Wells proved uncanny in his accuracy. It was as if some sixth sense, which was in effect his clear analytical brain, enabled him to see the shape of things to come as no lesser man of his generation ever did.

Land Ironclads published in 1903 contained a description of tanks and suggested how they might be used in trench warfare. In *War in the Air* (1906) he foretold air warfare which he said would take place long before 2000 A.D. and perhaps before 1950. Thirty years ago he anticipated the atom bomb in *The World Set Free*, the Wells bomb setting up atomic disintegration in a tiny fraction of bismuth.

His *Declaration of the Rights of Man* in 1941 was in advance of

the Atlantic Charter, and in *The Outlook for Homo Sapiens* (1942) Wells wrote: "When at last one side admits defeat and peace is proclaimed upon the world battlefield, what will be the situation? The defeated will be treated as incurably guilty parties. Instead of any biologically conclusive settlement there will be once again a punitive peace. The victors to the best of their ability will make the losers pay . . . no country in the

HERBERT GEORGE WELLS

world, even those that have preserved a technical neutrality—will emerge from the storm at anything like the level of civilisation at which it stands to-day. There will be less freedom of speech, less opportunity to speak freely, far more fear and far more danger of frantic mass impulses."

Wells came from a family of ordinary British working people. His father was in turn gardener, cricket coach and small shopkeeper; his mother was a domestic servant.

In his writings Wells has told us that little remained in his memory of that childhood world. Most of his days were spent in an underground kitchen. As he grew older the world about him took fuller shape. He saw that there were upper and lower classes, workers and more leisured folk. By the time he was

fourteen doubt had crept into his mind, he questioned the truth of what he was told. Religion as it was given to him was "queer, muddled stuff", morality thrust him into secret corners.

What he was taught at school hardly interested him until his schoolmaster set him to read science text-books in order to earn Education Grants for the school. This was a turning-point. A new world swam into his ken.

With a burning desire for more and more knowledge Wells revolted at what he realised was the sham education he had been given. From that day to his last breath he hated restriction and distortion of knowledge. He lashed out at a system of education that allowed the world to swarm with "mental cripples", he held it second only to murder to "starve and cripple the mind of a child".

Wells was never a favourite with academic fanatics. He knew that academic knowledge often does not outlast a lifetime and that the greatest mistake in thinking of the future is to regard anything as impossible.

After he left school he was apprenticed to a draper. This lasted only a short time, and in turn he became pupil teacher and chemist's assistant.

All this time he was reading voraciously, and succeeded in getting a scholarship at what is now the Imperial College of Science. Then came tutorial work until in 1895 Wells gave to the world his first book, *The Time Machine*. From that day his books, pamphlets and articles followed in quick succession.

He was twenty-nine when *The Time Machine* appeared and by the time he was forty he had published at least four score books and won world-wide recognition for his genius.

In so short a space it is impossible to detail all Wells's works. *The History of Mr. Polly; Kipps; Tono Bungay*, are novels that will never be forgotten. In the field of history his *Outline of History* sold in millions, and *The Science of Life* written in collaboration with his son and Julian Huxley, is one of the most fascinating scientific works ever written.

1933 saw *The Shape of Things to Come* which caused a sensation as a talking film, and before his death Wells was working on the script for a new film *The Way the World is Going*.

I knew Wells personally, and shall always be grateful to him for his kindness and interest in my work. It is a fact that whenever I write something which I think might be interesting I find that Wells wrote it twenty years ago, and much better!

He was never "smart" in writing or thinking; he was too big.

His hatred for well-trained fools never left him and he constantly reiterated the farce of the present examination system and stupidity of talking of "training for research". Sham academic research he called "unending weighings and measurings". The scholar who expressed no original thought he referred to as "wearing secondhand clothes". Devastatingly true.

Some of the passages in his *Research Magnificent* are quite as wonderful as the Bible. The most extraordinary thing was the clarity of his thought. He seemed to see everything as if it was printed before him. He had none of the false dignity of ignorance, and above all he appreciated the thread of life that runs through science and all objects. That any so-called scientific or learned society could exist without realising that Wells's name would have honoured them is the finest comment that can be made upon the very type of pretentiousness which he gave his life to conquer.

Wells never confused intelligence with memory. When last I saw him, not very long ago, he said to me: "I have always watched your research because I know you love it." I replied: "Yes, sir, but not the Research Magnificent!"

He had jealous detractors. All great men have. He spoke so strongly against all shams and falseness in life. With all his heart he fought to make men realise that without social planning on a world scale the future will be chaos.

He knew that death might come to him suddenly, almost unheralded but that did not daunt him or cause him to cease from work. He died as we think he would have wished to die, with his great brain active and his thought set on that Golden Age he so earnestly desired to see. A more noble mind has not yet lived.

SIR JAMES HOPWOOD JEANS, O.M.

1877–1946

WHEN Sir James Hopwood Jeans died the modern world lost a great astronomer, mathematician and natural philosopher, a man well known in international scientific circles and endeared to the ordinary reader who found in his writings a clear exposition of many hitherto unintelligible occurrences.

Jeans's books were an immediate success. They had a wide appeal, and as a "publicity agent" for relativity he did more to explain Einstein's unexplainable theory than almost any other scientist.

His broadcasts, too, "went over well". He had the gift of catching the listener's attention and, as it were, bringing the "mysterious universe" home to us.

Writing came easily to Jeans. He came of a family of journalists and his father, William Tullock Jeans, was a well known Parliamentary writer.

For six years James Jeans was at Merchant Taylors' School. First on the classical side, but later he turned to mathematics, and at the same time, like many other boys, enjoyed the thrills of experimental science.

Jeans used to say that it was his first visit to Greenwich when he was seven that started his interest in astronomy. His youthful imagination was fired by the wonders of the Observatory.

At Cambridge he was a scholar of Trinity College. In 1898 he was bracketed second wrangler, and two years later took a first in the mathematical Tripos and was selected Isaac Newton Student. In 1901 he became a Fellow and in 1904 University lecturer in mathematics.

For four years Jeans worked as Mathematics Professor in the United States at Princeton University but returned to Cambridge as Stokes Lecturer in Mathematics in 1910. His essay *Problems of Cosmogony and Stellar Dynamics* won for him the Adam Prize in 1917.

In 1906 he had been elected a Fellow of the Royal Society, and in 1919 he became its secretary, which post he held for ten years, when he retired to live in the country and devote himself to writing and lecturing. His most popular works are *The Mysterious Universe*, *The Universe Around Us*, *The Stars in Their Courses*, *The New Background of Science*, *Through Space and Time*, *Science and Music*.

Probably the most striking of Jeans's original work was that contained in two treatises, one which gained the Adam Prize, and the other, published in 1928, entitled *Astronomy and Cosmogony*.

He fully developed the Tidal theory of the origin of the solar system which is described also in his book *The Stars in Their Courses*.

SIR JAMES HOPWOOD JEANS

According to Jeans, terrific tidal forces are raised as one star approaches the sun's atmosphere, causing gaseous projections to be drawn out, then broken off and condensed into bodies as large as those of the sun's satellites. In the planets, tides are raised in the same way to form other satellites, but so vast is the ever expanding universe that not more than one star in 100,000 will have a family. There is little congestion of celestial traffic.

Regarding stellar radiation, Jeans first suggested that this

might be the result of combination and annihilation of two ether strains of opposite kinds which would amount to the dissipation of a certain amount of mass. In 1918 he calculated that if the sun's mass was diminished by only 1 per cent it would set free radiation and the sun would have an extra radiative life of 150,000,000,000 million years. Ten years later he suggested this as the source of stellar energy.

Jeans was sceptical of the possibility of life on other planets, but in 1944 he stated that he "would like to call an interplanetary conference as we might then be able to learn something from people of worlds 2,000 millions older than our own".

In his best seller *The Mysterious Universe,* published in 1930, Jeans revealed his belief that the universe showed evidence of some designing or controlling power. Something in common with our own individual minds, "not," he says, "so far as we have discovered emotion, morality or aesthetic appreciation, but the tendency to think in the way which for want of a better word we describe as mathematical."

Music was his hobby. He was a good organist and had two instruments installed at his Dorking home, one for his own use and the other for his wife, a Viennese musician whom he married in 1936. He raised a storm of protest from the Music Teachers' Association when in an address to its members he refuted the common idea that a pianist can put any emotion he pleases into a note by the manner in which he strikes a key. Jeans declared that "the tone quality of a single note is the same whether the key is struck by a finger or umbrella end."

He was President of the Royal Astronomical Society from 1925–1927 and of the British Association in 1934. In 1928 he was knighted, and in 1939 received the Order of Merit.

It might be true to say that Jeans's great discovery when summing up his own work was the limitation of his knowledge. In his *Background of Science* he writes: "The fact that the search for physical reality underlying the mathematical description of nature has so far failed does not, of course, imply that the earth must for ever fail . . . our positive knowledge of the road along which science is travelling is confined to that which lies behind it. We cannot say how much farther, if at all, the road extends in front, or what the far end is like; at best we can only guess."

There are many examples we can read of his popular sayings, such as "The stars are so hot that an area of surface the size of a postage stamp sends out enough energy to run a vast liner the size of the Queen Mary". "The universe is no longer a deluge of shot from a battery of machine-guns, but a stormy

sea with the sea taken away and only the abstract quality of its storminess left." "It looks as though the universe had exploded much as a shell explodes on the battlefield, and we are clinging on to one of the flying fragments."

Like many others, whose works are quoted in this book, Jeans was bent on passing on his knowledge as far as possible to all who are interested. The popularity of his works with non-technical readers is the measure of his success.

SIR ARTHUR STANLEY EDDINGTON, O.M.

1882–1944

At the turn of the 18th century a young assistant master at a Quaker School at Kendal, Westmorland, was turning his thoughts to the idea of atomic structure. His name was John Dalton, a man who was later known as the founder of the Atomic Theory.

A century after, at the same school, another youthful Briton also developed an interest in scientific matters; this was a boy, Arthur Stanley Eddington, who was to become one of the Chief expositors of Einstein's Relativity Theory, and like John Dalton, a chaser of atoms.

Eddington was born at Kendal in 1882 where his father was the Head of the Friends School. He attended this school and later went to Weston-super-Mare and on to Owens College, Manchester, where he distinguished himself by winning all possible honours and passing first class in Physics in 1902.

From Manchester Eddington went to Trinity College, Cambridge, where he became a scholar and, in 1904, senior wrangler. He took his B.Sc. degree at London University and obtained a scholarship for Physics in the final honours examination. He was also Smith's Prizeman at Cambridge and in 1907 was elected a Fellow of Trinity.

Already his name was connected with astronomical research, and in 1906 he was offered and accepted the post of Chief Assistant at the Royal Observatory, Greenwich. This he held for seven years when he was appointed Plumian Professor of Astronomy at Cambridge and the following year became Director of the University Observatory.

Briefly, in the main Eddington's work ran on these definite lines; research into the stellar system, the nature of the internal structure of stars and the extension of the relativity theory.

It was in 1910 that he published a paper showing that he had analysed 6,188 stars, and as a result of this detailed investigation Eddington advanced his theory that stars do not wander about the heavens in any "go-as-you-please" fashion, but on the contrary, move in two well ordered "star streams".

Eddington announced one of his great discoveries in 1924. This was the culmination of work in connection with the luminosity and mass of stars. He demonstrated that as the mass

of the star increased so did its luminosity, and in addition the luminosity per unit mass also grew greater.

This law was to benefit astronomers for it was then made possible to calculate the masses of stars whose luminosity was measurable.

Einstein's famous paper on relativity, of which there was then probably only one copy in England, came into Edding-

SIR ARTHUR STANLEY EDDINGTON

ton's hands in 1917. The two men were contemporaries, Einstein being a child of three when Eddington was born. As they grew to manhood their minds were grappling with similar problems and it fell to the lot of the British scientist to correct and interpret the German's theory of relativity to the non-scientific reader.

In the following year Eddington reported to the Physical Society on Einstein's theory and his ability in this direction

won the high commendation of Einstein himself. Eddington was able to render the relativity theory well understandable to those who found it impossible to follow the mathematical equations involved.

The Expanding Universe, published in 1933 contained the author's views of what happenings we might expect in a finite and spherical world according to Einstein. Eddington pictures the galaxies receding farther and farther from each other as would painted spots on an expanding balloon. So rapid is this expansion, he claims, that, assuming its continuation, the nebulae would recede and double their present distance from the earth in 1,300,000,000 years. Eddington states that when that time comes astronomers would have to use telescopes with double the aperture of those of to-day in order to observe such fascinating objects as well as we can at the present time.

A paper read by Eddington before the Royal Astronomical Society in 1944 entitled *The Recession Constant of the Galaxies*, sets forth what the writer calls "a time-table of the universe". In this he expounds views of the times that have elapsed since the universe "burst" and the limit of past time, called the time of creation, or the time when it was no longer possible for light to travel completely round the universe.

In 1919 Eddington led an expedition to the Isle of Principia in the Sea of Marmora to make observations of a total eclipse of the sun, in order to test one of Einstein's predictions that the path of light rays passing near to the sun would be slightly bent. These observations proved the prediction to be correct.

There is no doubt that Eddington made magnificent contributions to astronomy, physics and philosophy and opened up wide fields of research for others to explore. He wrote many popular books, among them being *The Internal Constitution of the Stars*, *Stars and Atoms*, *The Nature of the Physical World*, *Science and the Unseen World*, *The Expanding Universe*, and *New Pathways in Science*.

Eddington was awarded many honours and distinctions. In 1914 he was made a Fellow of the Royal Society and received the Royal Medal in 1928. He was President of the Royal Astronomical Society from 1921 to 1923, and President of the Physical Society from 1930–1932. In 1930 he was knighted, and in 1938 became the youngest holder of the Order of Merit.

Early in 1939 Eddington was a member of a group of influential men who signed an appeal directed to all peoples of the world and in particular to the leaders of the great German Reich asking for a "supreme effort to lay the spectre of war".

It has been said by those who knew him well that Eddington's life and work was inspired by religion. In the conclusion to the *Nature of the Physical World* he writes: "The religious reader may well be content that I have not offered him a God revealed by the quantum theory, and therefore liable to be swept away in the next scientific revolution. It is not so much the form that scientific theories have now taken . . . as the movement of thought behind them that concerns the philosopher. Our eyes once opened we may pass on to a yet newer outlook on the world, but we can never go back to the old outlook."

Earlier he wrote: "Life would be stunted and narrow if we could feel no significance in the world around us beyond that which can be weighed and measured with the tools of the physicist or described by the metrical symbols of the mathematician."

Eddington never married and when questioned as to his ideas on love he is reported to have said rather sadly: "Falling in love is one of the activities forbidden to the consistently scientific man."

The death of Eddington in 1944 deprived the world of a great scientist and a man of fine character. Of all men he knew that there is never any going back, but that "in each revolution of scientific thought new words are set to the old music, and that which has gone before is not destroyed but refocused . . . the kernel of scientific truth steadily grows; and of this truth it may be said: 'The more it changes, the more it remains the same thing.' "

CONCLUSION

"THEY MADE YOUR WORLD"

EVEN if it so be that you cannot greatly care for the life of anyone but yourself it is impossible to read of the struggles through which science in the past has grown without some measure of pity. Labour of this kind still needs our help rather than mere acceptance. It is so easy to see in every chapter of this book that these men were never content.

I mean content in the worst sense of the word. Their whole existence was a longing for improvement, for throwing aside something which did not satisfy their wish for truth, for seeking what might help others, to greater comfort, health, happiness or understanding.

That is the moral of this book. The men whose lives and work are described were pioneers. They seldom lingered to present their achievements to each other at a peaceful fireside. They wanted to be first, they wanted to win the race. Not for self-aggrandisement but to establish that progress had been made and could be used for the common good. They were individualists in the extreme. Unknown to history they have governed and shaped the world incomparably more than any King, Dictator or Emperor.

That is why I say that their example may help others to look forward or to encourage all that is original and good. The work of great men is never smug. It is an opinion definitely expressed for others to use freely. Should you not care at all for what has happened in the past you can at least be very proud to inhabit a world where such men as these have lived.

HEWSHOTT, 1947.